

# An Integrative Framework for Architecting Supply Chains

by

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Submitted to the System Design and Management Program  
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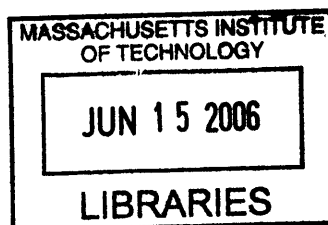
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## **Abstract**

This thesis explores the limitations of classic models of supply chain management, and proposes a new view based on the concept of value-driven supply chains, and a method of analysis and design based on the concepts of System Architecture.

A new supply chain process reference map proposed by Simchi-Levi and Fine is used to frame the architecture. The model revises and extends the de-facto standard reference model in the industry, SCOR 6.0, to reflect the new scope and concerns.

A method of analysis based on the understanding of the strategic intent of the firm, the characteristics of the environment in which the firm will operate, and the capabilities of the firm is proposed. Building on analysis frameworks by Shapiro and Fine, the analysis attempts to align the characteristics of the supply chain with the requirements of the different competitive strategies the firm may pursue, and explores environmental constraints through six lenses—regulation, industry structure, business dynamics, technology dynamics, customer preferences, and capital markets. The process reference map is used to frame the analysis of the capabilities of the firm in three dimensions: the production system, product development process, and the distribution system.

A prescriptive framework is developed and applied to two case studies: INDITEX (Zara) and General Motors.

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# Chapter 1

## Introduction

Attributed to Oliver and Webber (1982), the term “Supply Chain Management” has been used with several different meanings since its introduction in the early eighties—from clear-cut definitions based on the idea of system-level optimization<sup>1</sup> (Simchi-Levi et al., 2003), to broader definitions that use the terms “Supply Chain Management” and “Value Chain Management” interchangeably (Fine, 1998), the variety of ways the term is used is indeed so wide that even integrative efforts to track its historic use do not completely agree.<sup>2</sup>

Some points of agreement exist, though. One of them seems to be a trend toward broadening the scope of Supply Chain Management as a practice—from barely design and planning of logistic systems up to strategic planning of value chains.

In this new context, Lee (2004) questions the intrinsic value of classic metrics of supply chain performance such as speed and cost efficiency in favor of new ones—the so-called “Triple-A”: Adaptability, Agility, and Alignment, and new questions arise: What are the sources of supply chain adaptivity? What is the impact of corporate processes—and more specifically the product development process—on the supply chain? What are the constraints imposed by corporate capabilities? How can the different parties across the supply chain be aligned to support the corporate strategy?

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<sup>1</sup>Optimization of a number of objectives (such as system-wide costs) by manipulating a number of degrees of freedom (such as who/where/when makes each part of a product), and subject to a number of constraints (such as service levels)

<sup>2</sup>See for example Harland (1996); Chandra and Kumar (2000).

Fine (1998) suggests that there is not a single supply chain, but three essentially different supply chains interleaved, namely Product/service Fulfillment (the “classic” supply chain), Product Development, and Capability Development. From this standpoint, an open question is how these three chains interleave—how the different chains interface, and how they match their different relative speeds. From the perspective of the corporate architect, one would be interested in knowing whether it is possible to handle classic concerns of one supply chain (such as demand volatility in the product fulfillment supply chain) by strategic redesign of the other supply chains (such as altering the pace of the product development chain). While some work has been done in this domain, mostly in addressing the issue of matching products and supply chains (Fisher, 1997; Fine, 1998), the question remains largely unresolved. The objective of this thesis is to analyze the apparent paradigm shift in Supply Chain Management in the last few years, and provide an integrative model that can support the analysis of Supply Chains in this new context, extending the classic Supply Chain analysis (what we will call the *Fulfillment Supply Chain* to cover the *Product Development Process*, and the *Capabilities Development Process*—the process by which corporations accrue the necessary capabilities for developing, producing, distributing, and serving their products and services.

## 1.1 Thesis Organization

Chapter 2 provides the motivational background for this thesis; it discusses the limitations of the “classic view” of Supply Chain management and illustrates them with four short case studies.

Chapter 3 presents an alternative view of Supply Chain Management based on the concept of value-driven supply chains, and proposes a new approach to architecting supply chains that builds on a new supply chain process reference model proposed by Simchi-Levi and Fine, which we will call the L-model.

Chapter 4 presents a framework for the systematic analysis of supply chains, using the L-model as a guide for the analysis of the capabilities and constraints of

the firm, Fine's "gears" model for the analysis of the environment, and Shapiro's categorization of competitive strategies as a way to understand the implications of the firm's competitive intent on the supply chain.

Chapter 5 reviews different supply chain design frameworks proposed in the literature, and develops an integrative framework that takes the analysis developed in 4 as an input, and prescribes specific design decisions along five key design parameters of interest.

Chapter 6 applies the analysis framework to a case study of Zara, the fastest growing apparel retailer in Europe. Zara is interesting as a case study because it is largely an anomaly to the eyes of the classic view of supply chain management, and because it presents extreme values in most of the key dimensions identified in the analysis framework.

Chapter 7 applies the framework to the analysis of General Motors's supply chain. General Motors presents the case of a company whose supply chain model is facing important challenges, to some extent consequence of a limited view of the supply chain that needs to be changed. Two specific prescription that could be beneficial are hypothesized and discussed.



## Chapter 2

# The Classic View of Supply Chain Management

Understanding current SCM challenges requires to first understand how the practice of SCM has evolved historically—understand the concerns of the past, the methods used to address them, and how both concerns and methods have changed with time.

These changes can be observed just studying the evolution of SCM-related professional organizations. Take for example the National Council of Physical Distribution Management (NCPDM), founded 1963. In 1985 it changed its name to become the Council of Logistics Management (CLM), and during this stage, it used to define SCM in the following way:

Supply Chain is the process of planning, implementing, and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods, and related information from point of origin to point consumption for the purpose of conforming to customer requirements.

On January 1, 2005 the CLM changed its name again, this time to become the Council of Supply Chain Management Professionals (CSCMP). As of February 2005, the CSCMP's glossary working definition of Supply Chain Management had changed to the following one:

Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the logistics management activities,<sup>1</sup> as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, finance and information technology.

The two definitions are substantially different. The first one is very specific, and places special emphasis in cost and efficiency. It shows that SCM is no longer just about the physical flow and transformation of raw materials into finished goods, but also about market mediation—about matching what is produced with the customer’s requirements; in short, it is about *matching supply and demand*. It also conveys the idea that SCM manages not only physical flows of goods and materials, but also information flows.

In contrast, the second definition is much fuzzier, and opens SCM to a wider range or possibilities. It no longer talks about costs and efficiency, but about a “high performing business model.” The main concern is now collaboration and coordination inside the firm, and among multiple players in the chain, whereas the first definition implicitly focused on a single firm. It is longer and less rounded, probably a symptom that the definition it is still evolving.

Other definitions of Supply Chain Management exist, and the two presented are arguably as good as any others. What makes them interesting is that they *consistently* reflect how a thought-leading organization has changed its understanding of SCM

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<sup>1</sup>Also defined in a different entry in the glossary



at different points in time. They evidence the trend in the last 20 years toward broadening the scope of Supply Chain Management as a practice. The first one represents what Supply Chain used to be, and we will refer to it as the “Classic View.” The second definition represents where SCM is heading.

The Classic View has been very successful in the past, and is still the dominant model for a large number of companies (Fawcett and Magnan, 2002). In this chapter, we will explore what this view prescribes, why it has worked in the past, and what are its limitations for the future. We will first present the most relevant issues in detail, then we will study a number of real cases that do not fit well the classic view.

## 2.1 The problem with the Classic View

Figure 2-1 depicts a supply chain through the eyes of the classic view: a complex network of suppliers, manufacturers, and distributors delivering goods to end consumers. In the classic view, the Supply Chain Architect aims at finding “a minimal-annual-cost configuration of a company’s production and distribution network that satisfies product demands at specified customer service levels” (Geoffrion and Powers, 1995). In short, in the classic view architecting a Supply Chain is a design problem where cost is the major concern, service level is a given constraint, and placement of facilities, transportation modes, and inventory policies are the main design degrees of freedom left to the designer. This view presents a number of limitations:

1. It focuses on optimizing the wrong thing (minimizing the cost of operations instead of maximizing the value delivered)
2. It is biased toward accounting only the obvious costs—those that can be easily quantified. For example, flexibility is often left out of the equation.
3. It limits the number of design degrees of freedom to essentially the following decisions: how many network nodes to deploy, where to place them, how to connect them, and how to manage the intermediate stocks carried in each one.

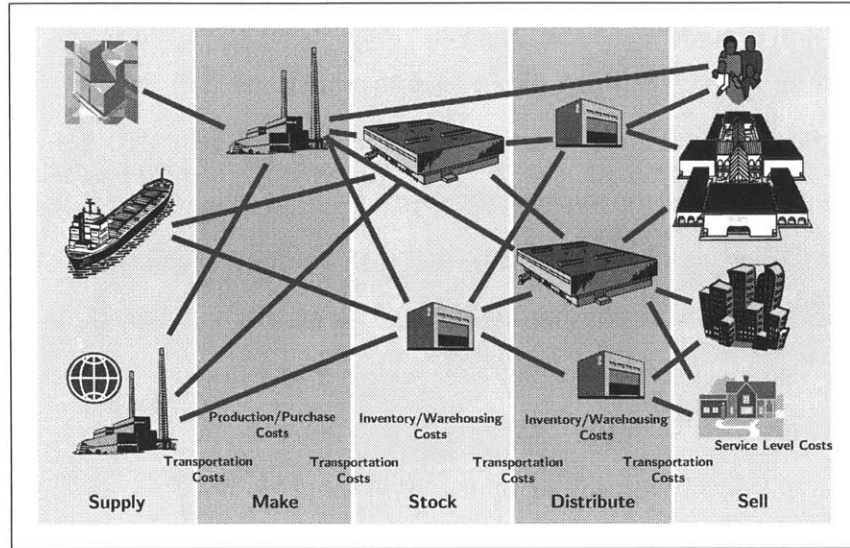


Figure 2-1: The Classic View of the Supply Chain

4. It promotes an static view of the Supply Chain—“design once, restructure it only eventually.”
5. It is biased toward considering short-term risks only: those associated with achieving a desired service level.

### 2.1.1 Overly zealous focus on cost and efficiency

Shapiro (1984) pointed out that Supply Chains are too often seen exclusively as cost centers, not profit centers. It is true: the objective of a company is to create more value, and that spirit must pervade the supply chain.

#### Optimizing the wrong thing

Efficiency in costs is certainly an important part of creating more value, but not all of it. While in some domains, such as commoditized mass-production industries, minimizing costs is the only possible way to generate value,<sup>2</sup> this is not universally true: the solution that minimizes costs is not necessary the one that maximizes value, and this is becoming more evident as companies start to seek competitive strategies based in supply chain factors other than costs, such as innovation or service.

<sup>2</sup>Provided that the product is above a certain quality threshold

## Accounting only for the obvious costs

A second problem related to cost focus is *what* gets factored-in as costs. Often only obvious costs are accounted, such as inventory or transportation costs. Less obvious, but also important costs are often ignored just because they are more difficult to quantify. Supply chain breakdowns or long-term impact of stock-outs fall in this category.<sup>3</sup> As a consequence, resiliency, responsiveness, and flexibility are not properly valued.

## Hygienic factors

Greis and Kasarda (1997) points that in historic perspective, cost was relegated to a second plane by Quality in the 80's, Quality by Delivery Speed in the 90's, and speculates that Speed will be superseded by Agility in the 00's. This does not mean, however, that cost, quality or speed are no longer important today. It just means that they are no longer considered sources of strategic advantage, but just *hygienic factors*—something that everybody takes for granted. Therefore, getting them right no longer ensures success, but getting them wrong still yields to failure.

### 2.1.2 Important design degrees of freedom are ignored

The classic view leaves important aspects such as product design or process design out of the drawing board. This is reasonable for simple products that do not change very fast, such as sugar or nails, but as products increase in complexity, variety, and frequency of change, product design represents an important point of leverage that the Supply Chain architect can't ignore.

Design for Manufacturing (Ulrich and Eppinger, 2004, pag. 211) aims at changing the product in the design stage to better match the characteristics and capabilities of the manufacturing process to be used. Design for Supply Chain (Lee et al., 1993, 1997) attempts to do the same with supply chain capabilities and end demand char-

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<sup>3</sup>There is a reason for this—often it is hard to estimate even the most obvious variables for certain industries, such as stock-out rates in retailing (Raman et al., 2001), and translating them into costs is even harder, as “soft” metrics such as brand erosion can't be estimated easily.

acteristics. 3-Dimensional Concurrent Engineering (Fine, 1998) aims at matching concurrently product, process, and supply chain.

### **2.1.3 Supply Chain design is static**

In the classic view, the objective of the supply chain architect is to find *one* network configuration that would yield the lowest costs given a certain specified service level, and that will remain unchanged for an extended period of time.

#### **The supply chain must change as the market evolves**

As supply chain operations become more global, the old static view of the markets becomes more and more inappropriate. For example, on May 20, 2005 China announced a raise of tariffs on textile and apparel exports that in some cases reached a 400% increase. If the initiative were to proceed, apparel manufacturers outsourcing to China would have to either take the hit, or quickly adapt their supply chains to source elsewhere.

#### **The supply chain must change as the product moves in its life cycle**

Products in different stages of their life cycle have different supply chain needs, and as the life cycles accelerate, the ability to quickly adapt the supply chain becomes more valuable. For example prior the launch of the Xbox console, Microsoft required a great flexibility in manufacturing in order to be able to change design specifications very quickly (O'brien, 2001; Lee, 2004). Microsoft also needed to reach the main target markets, the US and Europe fast. That meant to manufacture in Hungary and Mexico via Flextronics, a third-party electronics manufacturer. Both Hungary and Mexico have less cost effective labor than China, but both countries are closer to the target markets and have greater flexibility to accommodate changes. Once the product was in the market and Sony, their main competitor, slashed the prices to strike back, Microsoft needed to become cost effective, so that Flextronics took the now stable designs to China.

## **The supply chain must change as the product mix changes**

Sometimes it is unavoidable to have to deal with a portfolio of products in different stages of their life cycle, or with very different products in the nature of their demand. In these cases, the “one size fits all” approach that is implicit in the classic view can be very inappropriate. Instead, we will probably need to overlay a number of different supply chains specially tuned for the needs of different types of products.

### **2.1.4 Bias toward considering only short-term risks**

Aside the risk of the supply chain not being cost-effective, not achieving a certain service level is the only risk that is explicitly present in the classic view. The problem is that often only the obvious factors are included into the risk equation. More specifically, implicit in the risk of not achieving a certain service level should be the risk of supply chain breakdown, and therefore, supply chain resilience. However, examples such as the Toyota Aisin Fire (section 2.3.1 on page 27) or the Nokia/Ericsson Albuquerque Lightning (section 2.3.2 on page 29) remind us that this factor is often ignored.

Other important risks that are not related to service level exist, and are starting to become increasingly important, such as the risk of knowledge or capability leaks in the sourcing process (Fine and Whitney, 1996), or the risk of supply chain disintermediation (Fine, 2003). In short, the classic view deals only with short-term *tactical* risk, not with long-term *strategic* risk.

## **2.2 The Virtues of the Classic View**

In spite of its many defects, the classic view has been historically very successful. First, the concern it addresses (minimizing essential operating costs) is tightly linked to the main concern we actually want to address (maximizing value), and it has the advantage of being much easier to measure. In addition, the design degrees of freedom chosen have great leverage, are simple and well understood, and are reasonably easy

to actuate on—which increases the chances of success, especially in situations where limited technological infrastructure is available.

Therefore, suboptimal solutions produced by the classic view have traditionally been good enough for most cases of the past. However, the limitations of the classic model become apparent as industry competition tightens and becomes more global, product development cycles shorten, technology changes more rapidly, and customer demands greater product variety and customization.

## 2.3 Four examples

The following section presents four recent examples in context that illustrate the limitations of the classic view: the Toyota Aisin Fire, Ericsson/Nokia Albuquerque Lightning, the INDITEX Production System, and Dell’s Supply Chain model.

The Toyota Aisin Fire is an example of large-scale fast supply chain reconfiguration. It illustrates the dangers of single sourcing, the sometimes unavoidable tradeoffs between costs and resilience, and how close relationships with providers can turn into an advantage on a crisis. It also shows us that lean manufacturing environments making extensive use of the just-in-time (JIT) paradigm can be less fragile than it could appear in a first analysis, and sets the stage for the discussion of modular and integral supply chain architectures.

The Philips Albuquerque fire exemplifies how being fast to sense changes in the environment, and being fast to react and adapt the Supply Chain to the new conditions can determine the fate of companies. It also serves as an example of how having the capabilities to change the product design fast can help supply chain reconfiguration.

The Zara (the INDITEX Production System) is probably one of the best examples of what is usually called “agility” (a term that we will revisit later in chapter 5 on page 57) and fast demand sensing and response. It is an example of a situation where seeking just supply chain efficiency is not the right thing to do, and presents the case for make-buy decisions, vertical/horizontal integration, integrated teams and several other interesting issues that fall out of the scope of the classic view of the supply

chain.

Finally, Dell complements Zara introducing the concepts of push-pull boundaries, channel disintermediation, barriers to exit (by comparison with HP), and virtual integration. It also explains how product architecture can be leveraged to break the traditional tradeoff between product variety and demand uncertainty.

### 2.3.1 The Toyota Aisin Fire

In 1997 Aisin Seiki (“Aisin”) was the sole supplier of 98% of the brake fluid proportioning valves (*P-valves* in industry parlance) consumed by Toyota Motor Co. (“Toyota”) in Japan. At a cost of about \$7 each, P-valves are an inexpensive, but very important component of any car: if supply is interrupted, it is not possible to assemble car braking systems, and production lines must be stopped.

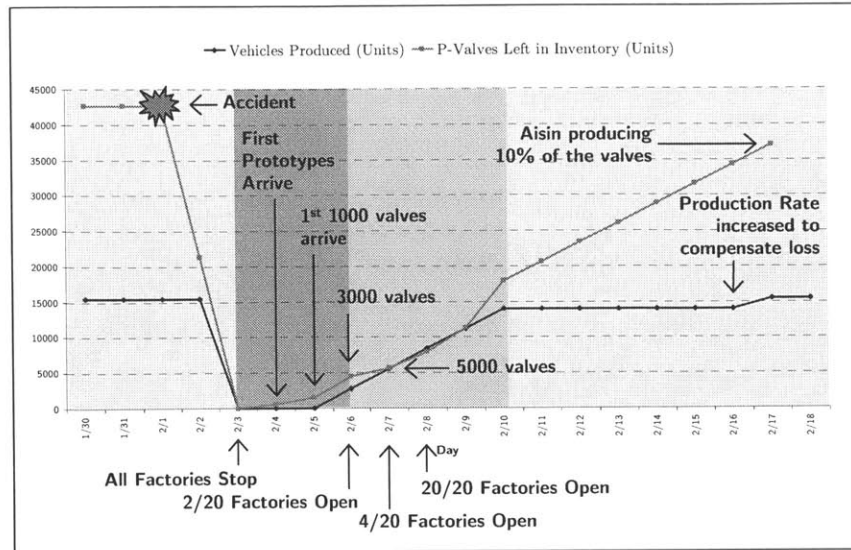
On Saturday, February 1, 1997 a fire stopped Aisin’s main factory in the industrial warren of Kariya, where other Toyota providers are located. Initial evaluation of the damage estimated in two weeks the time to restart the production again, and six months for complete recovery.<sup>4</sup>

The situation was critical. Toyota was facing a season of great demand, and plants were operating at full capacity, producing close to 15,500 vehicles per day. Conforming to the Just-in-Time (JIT) principle of the Toyota Production System, only two-three days of inventory were available on stock at Toyota, giving only a margin of a few days before the plants would have to come to complete stop.

Immediately after the accident, Toyota initiated a recovery effort with the help of their providers to restructure the whole Supply Chain of P-Valves. Blueprints of the valves were distributed among providers of any kind, and engineers from Aisin and Toyota were relocated to provider facilities and other surrounding companies, such as Brother—a manufacturer of printers and sewing machines. Existing machinery was adapted to build the valves according to Aisin and Toyota’s specifications, and new machinery was acquired in the spot market.

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<sup>4</sup>Valerie Reitman, “To The rescue: Toyota’s fast rebound after fire at supplier shows why it is tough,” The Wall Street Journal, 8 May 1997.



Source: author's estimates based on information published in The Wall Street Journal, Japan Economic Newswire, and Sloan Management Review (Valerie Reitman, "To The rescue: Toyota's fast rebound after fire at supplier shows why it is tough," The Wall Street Journal, 8 May 1997. "Toyota's fire caused production cut at 70,000 units," Japan Economic Newswire, 17 Feb. 1998 (via Factiva), and Nishiguchi and Beaudet (1998))

Figure 2-2: Impact of Aisin Seiki Co. Fire in Toyota

Figure 2-2 follows the evolution of production and inventories during the crisis. Factories came to complete stop for barely three days, and full production was restored in less than one week. The accident initially cost 7.8B Yen ( $\approx$ \$65M) to Aisin and 160B Yen ( $\approx$ \$1.3B) to Toyota (Nishiguchi and Beaudet, 1998). However, it is estimated that the damage was reduced to 30B Yen ( $\approx$ \$250M) with extra shifts and overtime.<sup>5</sup> In addition, Toyota issued a \$100M token of appreciation to their providers as a gift for their collaboration.<sup>6</sup>

One of the most controverted aspects of this crisis was why Toyota had only one supplier for such a critical component. Toyota used to have at least two suppliers for each component after the Great Hanshin Earthquake in 1995, when Toyota was forced to close all its assembly lines due to a similar disruption in a brake parts provider.<sup>7</sup> Another one is why only a very limited amount of inventory was being carried, since P-Valves are small (about the size of a box of cigarettes) and inexpensive.

<sup>5</sup>Valerie Reitman, WSJ 8 May 1997.

<sup>6</sup>Valerie Reitman, WSJ 8 May 1997.

<sup>7</sup>"Toyota to avoid producing parts at sole line", Japan Economic Newswire, 8 February 1997. Accessed through Factiva



According to Kiyoshi Kinoshita, Toyota's general manager of production control, single sourcing and holding almost no inventory was calculated risk.<sup>8</sup> Toyota's single sourcing allows Aisin to achieve economies of scale in P-valve production, and offer high quality at very low costs to Toyota.

A simple back-of the envelope calculation can provide a rough estimation of the value Toyota is placing on Aisin as a supplier. Aisin provides about \$33M worth of P-Valves to Toyota per year. The 1997 fire cost Toyota a minimum of \$250M. If cost efficiency were the only concern, even in an optimistic scenario, Aisin should be more than 80% cheaper than competitors during the next 10 years to compensate these costs. In short, it is difficult to explain this decision in the light of the classic view.

### **2.3.2 The Philips Albuquerque Lightning**

On March 17, 2000 a lightning caused a fire in a Philips Semiconductor Factory in Albuquerque, New Mexico.<sup>9</sup> The factory provided several types of Radio Frequency Chips (RFC's) for mobile telephones to Ericsson and Nokia. Fire, smoke and water used in fire exhaustion destroyed or contaminated virtually all the silicon stock in the factory.

Nokia detected unexpected delays in incoming orders from Albuquerque three days after the fire and contacted Philips to figure out what was happening. Philips told Nokia that the production was expected to be halted during one week. Nokia attempted to send engineers from Dallas to Albuquerque to get a first hand evaluation of the damage, but they were unable to gain access to the plant. Order monitoring frequency was increased from weekly to daily. On March 31, two weeks after the fire, Philips confirmed what Nokia was already suspecting: months of orders would be disrupted.

Nokia changed the product design to use chips from other providers. New chips were obtained from alternative suppliers in the US and Japan, who took the orders

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<sup>8</sup>Valerie Reitman, WSJ 8 May 1997.

<sup>9</sup>See for example: Almar Latour, "Trial by Fire: A blaze in Albuquerque sets off major crisis for cell-phone giants," The Wall Street Journal, 29 January 2001.

with only five days lead time due to the importance of Nokia as a customer. Only one out of the five components Philips was providing to Nokia was found to be impossible to get from other providers. Nokia put pressure on Philips to know the details of capacity allocation in other plants and ultimately got the orders rerouted to two factories in the Netherlands and China. Overall, production was not disrupted for Nokia.

Engineers at Ericsson had been informed of the fire by Philips three days after the incident, but it took the news four weeks to go through middle management and reach upper management. Only after five weeks Ericsson realized how critical the situation was. It was then too late to grab capacity from Philips, which had been taken by Nokia, and Ericsson didn't have alternative suppliers since 1990, when in an effort to reduce costs and streamline the Supply Chain, Ericsson had eliminated backup providers.

At least \$400 million were lost in potential sales. Ericsson had to rely on an insurance claim against the fire to cover part of the loss. Overall, a mix of component shortages, wrong product mix and marketing problems were estimated to have caused a \$1.68 billion loss to Ericsson cell phone division in 2000, and ultimately forced Ericsson to exit the cell phone market.

### **2.3.3 INDITEX, Integration, and Efficiency**

Zara is the largest brand of the Spanish fashion retailer INDITEX, a \$5.7 Billion Global-500 company in 2004, with a sustained 24% CAGR 1996-2003, listed in 2003 and in 2004 in the Wired Top 40 list of the most innovative companies of the world.

Zara introduces some 12,000 new items per year ( $\approx 300,000$  SKU's), about 4 times higher than industry average, and has cycle times as short as 3 weeks, 12 times faster than industry average—which allows them to introduce about half of the items in-season. In addition, Zara outperforms competitors in inventory management: mark downs to get rid of excess inventory account for only 15-20% of the sales, while industry average is 30-40%<sup>10</sup>. Stores receive orders two times per week, and collection

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<sup>10</sup>Source: INDITEX Press Dossier

renewal can be extremely fast; an example commonly mentioned is how the complete collection of their stores in New York was transitioned towards black-dominated garments in barely two weeks after the terrorist attacks of September, 2001 (Fraiman et al., 2002).

The way Zara manages the Supply Chain is counterintuitive in the light of classic view of Supply Chain Management.<sup>11</sup> First and foremost, it is vertically integrated in an industry that tends to the opposite. In fact, about half of the garments are produced locally, instead of following the trend in the apparel industry of sourcing all the production overseas. They are heavily dependent on logistics and short lead times, but their logistics operations are centralized in two distribution centers in Spain, one of them placed in arguably one of the worst possible locations in Europe in terms of logistics. They do not rely on forecasts over aggregated demand information; instead, stores, which are owned, run their own forecasts based on local, unaggregated data. Inventory is loosely tracked and full accuracy is not even seek (McAfee, 2004). Factories and distribution centers are not run at full capacity: factories run on a single shift most of the time, and so are distribution centers—in fact, a second distribution center was opened to double total distribution capacity when the first one was not even reaching a 50% utilization (Ferdows et al., 2003). The same applies to manufacturing and transportation batches: in order to keep the delivery cycles stable, orders are not delayed if quantities do not reach a certain economic order quantity (Ferdows et al., 2004). IT is completely insourced, yet IT spending as a percentage of revenue is about five times smaller compared to the average apparel retailer in the US (McAfee, 2004). Finally, marketing, design, procurement and manufacturing are tightly integrated in the design process.

### **2.3.4 Dell and Product Design**

As of September 2005, Dell was the world's #1 direct-sale computer vendor, and is challenging HP in the dominance of the worldwide PC market.<sup>12</sup>

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<sup>11</sup>An in-depth analysis of Zara is presented in chapter 6.

<sup>12</sup>Source: Josh Lower, Hoovers —<http://www.hoovers.com>.

Dell's success is often attributed to a combination of its direct-to-customer approach and operations excellence, but paradoxically some of the key enablers of Dell's advantage rely more on product design techniques rather than supply chain techniques.

Personal computers are highly *modular*, and exhibit a large degree of *commonality* across different models; this means that a computer is assembled from a set of standard components that can be used for other models as well.

Modularity allows Dell to pool risk at the component level: while Dell provides a wider range of models, and in addition they all are highly customizable, no finished goods are kept in stock. Only components are stocked, not even by Dell, but by the component provider through special vendor managed inventory (VMI) agreements. Dell only sets the target for inventory levels and tracks vendor compliance (Kapusinski et al., 2004). Furthermore, a modular product architecture makes possible for Dells to implement a highly modular Supply Chain, where components are multiple-sourced, and providers can be easily replaced in case they fail to meet the performance expectations—both in cost and in service levels.

In addition, since individual components obsolete slower than the end products, modularity allows Dell to mitigate the risks of product obsolescence and introduce products faster than competitors using a conventional distribution channel and building inventory of finished goods.

# Chapter 3

## A new view of Supply Chain Design

A much broader understanding of “lean,” or even a neo-lean model that extends the traditional lean manufacturing model to a system-wide perspective, is needed. Extending the “pull” logic that is at the heart of lean production to the entire value chain . . . requires systemic change, as well to modifications to all aspects of production, design, and logistics. Shifting to such a systemic view is often difficult because it may require sacrificing some local optimization to enhance system-wide performance.

– Matthias Holweg and Frits K. Phil<sup>1</sup>

The first step toward an integrative model is to develop a common language. This chapter presents an alternative view of Supply Chain Management based on the concept of *global optimization*, defines the tasks involved in architecting a supply chain, and presents a new process reference model that extends existing reference models to overcome the limitations presented in chapter 2.

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<sup>1</sup>Holweg and Pil (2004, pag. 3).

### 3.1 A New View

Building on Simchi-Levi et al. (2003, pag. 1), we present the following definitions of Supply Chain Management, and Supply Chain Architecture:

**Supply Chain Management** is a set of approaches utilized to integrate procurement, sourcing, production, distribution, and sales of products in order to maximize *systemwide* delivered value.

**A Supply Chain Architecture** is a set of high-level decisions taken over a number of design degrees of freedom of a supply chain reference model.

**A Supply Chain Reference Model** is a description of the *form* of the Supply Chain—that is: an abstract description of the different component parts of the Supply Chain as a system.

**A Design Degree of Freedom** is any feasible design decision the [Supply Chain] Architect wants to consider in any part of the reference model, as long as he has decision rights over it.<sup>2</sup>

This new definition proposes a value-driven, systems-based approach to Supply Chain Management, and a view of Supply Chain Architecture based in two key concepts: an abstract model of the supply chain as a system (the reference model), and a number of design decisions taken in parts of the model. These aspects will be explored in detail in the next sections.

A question arises immediately—how can we compare two alternative architectures? The simple answer is that it can't be done. In-depth performance of an architecture can't be assessed before a detailed design is done.<sup>3</sup> It is possible, however, to assess qualitatively how well the strengths of the architecture fit the strategic intent of the firm, its capabilities, and the environment in which the supply chain will operate. In this way, the architect can identify those architectures that are mostly

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<sup>2</sup>We will call a *design space* to the set of all possible combinations of decisions.

<sup>3</sup>In fact, further evaluation of the detailed design may reveal that an apparently good architecture is not as good as it appeared, and the Architect might have to return to the drawing board.

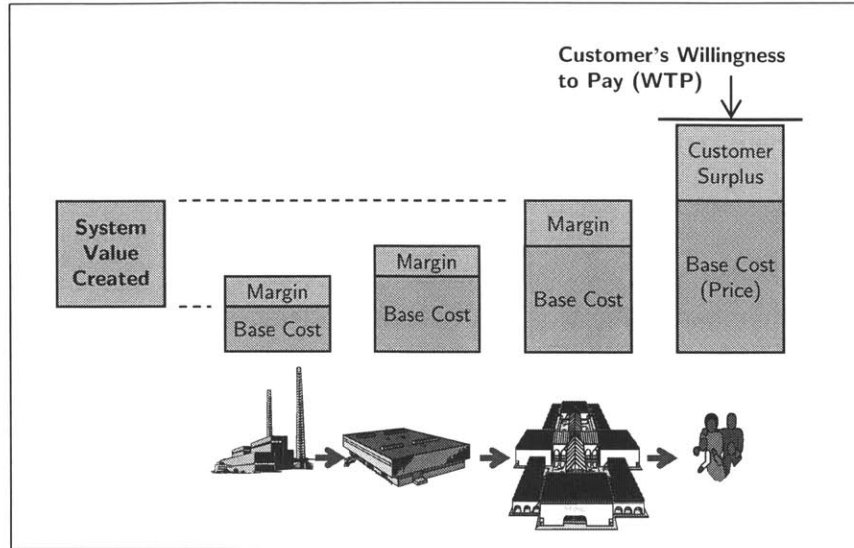


Figure 3-1: Value creation across the Supply Chain

wrong, and narrow down the design space before starting the detailed design process. Tradeoffs between the different dimensions are unavoidable, but good architectures can weaken the inherent tradeoffs between the dimensions of interest (Stock et al., 1998). These aspects will be explored in detail in chapter 4.

## 3.2 Value-driven Supply Chains

According to our definition, Supply Chain Management (SCM) is, first and foremost, about enabling systemwide value creation. Therefore, we need to understand how value is created, and how is it spread along the supply chain.

### 3.2.1 The sources of value

Customer value, or customer surplus, is materialized when the customer is able to get a product that matches his preferences at a price that matches his willingness to pay (WTP). The Supply Chain contributes to both objectives, first by reducing overheads and with them, overall product costs; second, by matching the right product with the right customer, hence *enabling* the extraction of a greater share of customer value,

which can then be spread along the chain, as Figure 3-1 illustrates.<sup>4</sup>

As an example, Dell’s customer value comes from affordable, technologically updated, highly customized PC’s delivered quickly. All of these characteristics have been enabled by specific Supply Chain design decisions, such as application of component pooling, management of push/pull boundaries, channel disintermediation, virtual integration, and demand steering through dynamic pricing. The case of Zara is similar: customer value comes from affordable fashion with reasonable quality, up to date with the latest trends in the market—all of which have also been enabled by specific Supply Chain design decisions such as vertical integration, or integrated design, procurement, and manufacturing. Understanding the sources of value is understanding the key drivers of supply chain decisions.

Following the example, Zara is willing to pay the higher costs of manufacturing in Spain instead outsourcing all the manufacturing overseas in order to obtain flexibility to introduce more products in-season; in the same way, it is willing to pay the price of manufacturing and logistics capacity underutilization to get shorter lead times.

Toyota valued quality and cost over resilience and, despite the spectacular recovery after the Aisin fire, Toyota had to pay the consequences of a more fragile supply chain. Ericsson was less fortunate and had to exit the market.

### 3.2.2 The importance of *systemwide* value creation

Different parties in the Supply Chain have different, often conflicting interests, but as companies become dependent on their partners across the chain, it becomes more important to maximize the value created across the supply chain as a whole—*systemwide*, not only thinking in one of the interest of a single party.

Consider the following example: Lexus is known to limit the number of dealerships in order to ensure that their dealers sell more vehicles per store than any other brand

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<sup>4</sup>This view agrees with Fisher (1997), who identifies two main functions for any Supply Chain: one is the *physical* function of moving goods and raw materials across a transformation chain; another is a *market mediation* function consisting in “matching supply and demand.” The first is often associated to the upstream Supply Chain, and the second to the downstream Supply Chain.



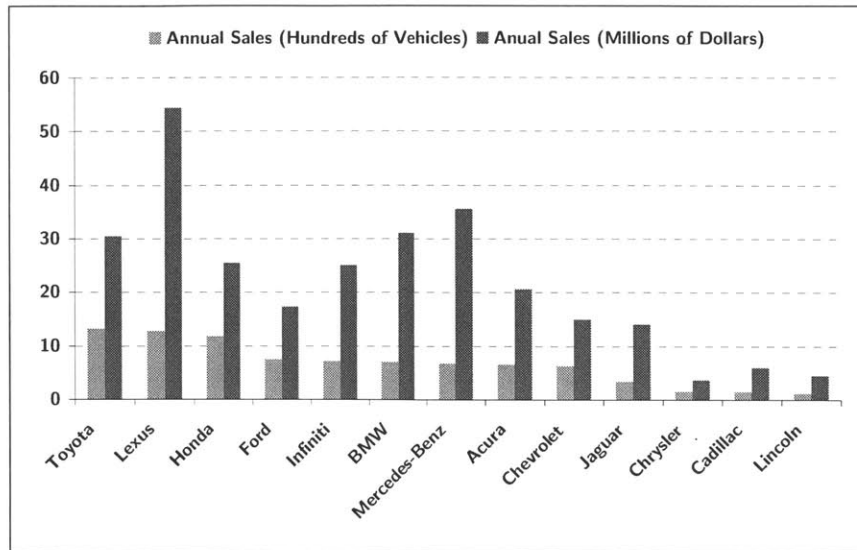


Figure 3-2: Performance of Lexus's Dealerships

(with the only exception of Toyota),<sup>5</sup> gives generous margins to dealers, and never reduces them. By doing this, Lexus enables their dealers to get the best showrooms and salesmen, and to provide the best customer service—which results in customer satisfaction rates over 99%. In addition, Lexus maintains a closer relation with the dealers, with whom they meet four or five times per year to get ideas for improving Lexus's operations and product offering. Overall, Lexus is maximizing value creation, but in order to do so, it is following a number of supply chain practices that may result counterintuitive in the light of the classic view, such as using a mostly pull-based supply chain fed with variable production, which minimizes the pressure on the dealer's parking lot. This contrasts with the forecast-driven, mostly push supply chains commonly used by car manufacturers such as GM,<sup>6</sup> where the dealers commit to a certain volume of sales and cars are pushed to the dealer's parking lot with little sensitivity to actual demand—leading to lower margins, as discounts must be used to get rid of cars stuck in the parking lots.

Thinking in terms of the interests of a single partner may backfire in the future.

<sup>5</sup>Lexus dealers sell on the average \$1,280 cars/year, barely 40 units less than Toyota, and twice as much as Chevrolet and Mercedes, which at an average selling price of \$42,500, make Lexus dealerships the most profitable dealerships in the US—see figure 3-2 for the details. See for example Fahey (2004).

<sup>6</sup>GM will be presented in detail in chapter 7.

That doesn't mean that the days of pressuring providers for lower costs have come to an end; in fact, that practice will most likely prevail in many industries, but we increasingly see examples of companies that realize the importance of caring for their partners. Anderson et al. (1999) present evidence of cycles in the machining industry caused by the Bullwhip effect, which could be avoided through closer collaboration of suppliers and providers. These cycles endanger the survival of upstream providers, which would impact downstream customers in the long term with longer lead times for equipment procurement and higher prices due to upstream unrest. Fine (1998) presents the case of a manufacturer of roller lifter valves for Chrysler's Jeep Grand Cherokee V-8 engines. The valves are assembled from metal parts cast using a clay of a unique chemical composition, whose provider had been losing money on the business for a long time. The provider was decided to abandon the business, and a production disruption could have occurred if Chrysler didn't discover the situation on time.

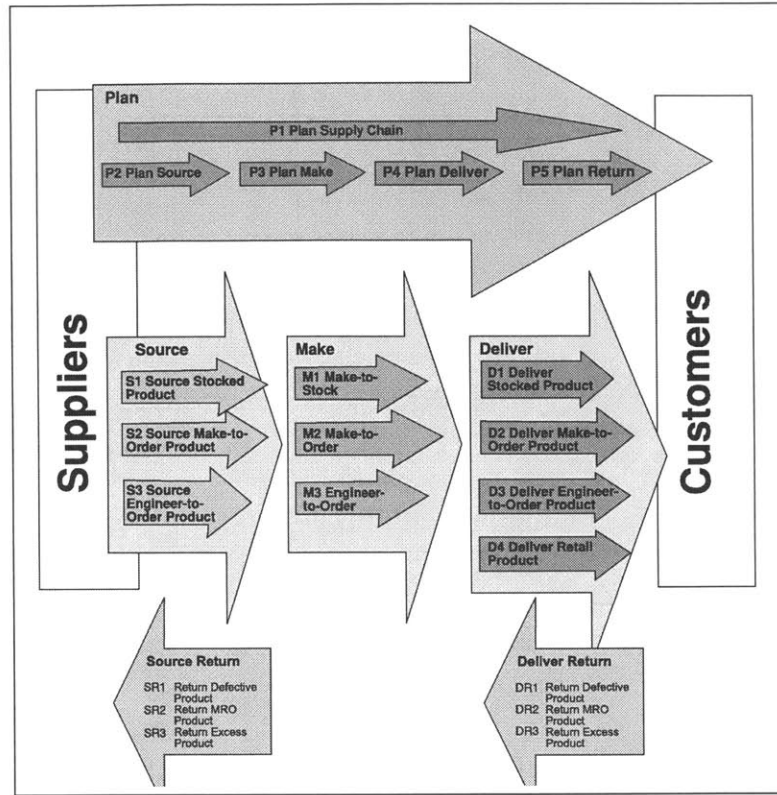
### 3.3 A New Supply Chain Reference Model

According to our definition, a reference model serves as a common language in which the architecture is defined. We therefore need to choose one such reference model in order to do architecture, either by adhering to an existing standard reference model, or by defining a new one.

#### The SCOR Reference Model

Figure 3-3 presents the high-level description of the Supply-Chain Council's *Supply Chain Operations Reference-model (SCOR)* (Supply-Chain Council Inc., 2003), a supply chain process reference model sponsored by about 1,000 companies worldwide and recognized as the de-facto standard in the industry.

SCOR provides a comprehensive process map for supply chain planning, sourcing, manufacturing, distribution (delivery), and reverse logistics ("return"), suggesting performance attributes and metrics, and documenting "best practices" for each of these processes. However, SCOR conforms to the classic view of supply chain, and it



Source: Supply-Chain Council Inc. (2003)

Figure 3-3: SCOR 6.0 Reference Model

is unsuitable to describe the alternative view we propose: first, it requires, but it does not address the processes for coordinating the supply chain; second, it explicitly leaves out of the problem of designing a supply chain the product development process, the capability-building processes (e.g. research and development), and the sales process.

### An alternative reference model: the L-Model

Figure 3-4 presents the high level view of a new process map proposed by Simchi-Levi and Fine (Simchi-Levi et al., Forthcoming), which we will call the *L-Model*.<sup>7</sup> This model extends the classic view of supply chain embedded in SCOR to make it suitable for describing a new view of Supply Chain Management.

Out of the six core processes depicted in figure 3-4, the bottom four represent

<sup>7</sup>Originally, Simchi-Levi and Fine didn't give a name to the model. The name "L-Model" we will use in this thesis to refer to it for the sake of brevity makes reference to the shape of the representation of the two chains interweaved.



raises awareness of the implications of decisions taken at different points—hence promoting Development/Fulfillment alignment. Overall, the L-model represents a *systems approach* to Supply Chain Design, and helps the designer to think in terms of Global Optimization (Simchi-Levi et al., 2003, pag. 2). In addition, the L-model presents the product design and development process as a chain that transforms organizational capabilities (knowledge, processes, technology...) into designs ready for manufacturing and launch.

The L-model also provides a framework for understanding how different concerns the supply chain design must address—such as cost, demand risk,<sup>8</sup> or resilience—are perceived in different points of the chains. These concerns are a product of the corporate strategy, internal constraints, and the characteristics of the environment in which the company operates, but their relative importance is not uniformly perceived across the chains.

For example, in the fulfillment chain, cost will be the dominant concern for procurement and manufacturing in most of the industries, whereas demand risk will become the dominant concern as we get closer to the end demand (e.g. in retailing). In the same way, the development chain we will see the same happening between long term product line and production system evolution, and short term product mix and match.

### 3.4 Design Degrees of Freedom

In the process of designing a Supply Chain, the Architect must first take number of high-level decisions, such as:

- How are the flows in the Supply Chain going to be regulated? Shall the Supply Chain follow a forecast-driven, *push* strategy, or shall it follow a more demand-driven, *pull* strategy? Or shall it be a hybrid solution?

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<sup>8</sup>The term “Demand Risk” refers to the value at risk due to demand uncertainty, which is tightly related to demand uncertainty, product contribution margin, and salvage costs

- Shall the inventory be centralized, or distributed across a network of distribution centers?
- Shall the relationship with providers of a certain component be purely transactional, or build instead long-term relationships?
- Shall production be global or local?

Essentially, any high level design decision can become a design degree of freedom, and deciding how many to consider, their types and the level of detail to consider is at the solely discretion of the architect, but as a rule of thumb:

1. The Architect's design degrees of freedom shall refer to *what* is to be done, not *how* it is to be done, leaving room for creativity at the detailed design level.<sup>9</sup> For example, after deciding that we will use a sparse distribution network, the detailed design will still need to determine how many distribution centers will be, and where to place them.
2. If we were to split Supply Chain decisions in three categories: Strategic (long-lasting effect on the firm), Tactical (updated between once every quarter, and once every year), and Operational (day to day decisions) (Simchi-Levi et al., 2003, pags. 8-9), then Architecting decisions would fall in the Strategic category, and Detailed Design in the Tactical category.

Ideally, the larger the number of degrees of freedom explored, the closer the design will be to the optimal solution. However, each new degree of freedom adds more complexity to the design process, hence the Architect must find a compromise between optimality and tractability.

Additional limits to the number of degrees of freedom to use are imposed by the internal constraints of the company such as budget or time restrictions that may make unfeasible to even consider certain degrees of freedom. For example, a distribution system may already be in place in the company, and the architect would have to adapt

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<sup>9</sup>This is commonly known as the *What, not How* Principle in Systems Architecting.

to the old design instead of implementing a whole new one. In addition, external constraints exist, such as government regulation: even if the architect believes that the best possible design requires to offshore factories, government restrictions may impede it.





# Chapter 4

## Analyzing a Supply Chain

In chapter 3 we defined Supply Chain Architecture as a “set of decisions over a number of high level supply chain design degrees of freedom”—where a *high-level supply chain design degree of freedom* is loosely defined as any long-lasting supply chain design decision taken at the sole discretion of the architect, that is high level enough not to constrain further detailed design. Simplifying, the problem of architecting a supply chain can be formulated as:

Given the firm’s capabilities, competitive environment, and competitive strategy...can we identify a number of potential supply chain architectures that fit the competitive environment and support the firm’s competitive strategy by leveraging the firm’s capabilities?

This chapter explores the first step in the problem of architecting a supply chain: how to systematically analyze and characterize the high-level objectives of the supply chain, the competitive environment in which the supply chain will operate, and the specific capabilities of the company.

Sections 4.1 through 4.3 frame the problem by providing definitions for strategy, environment, and capabilities, and a categorization schema for each one. Section 4.4 provides a preliminary list of degrees of freedom that the supply chain architect may explore, and proposes a systematic method for taking decisions along these degrees of freedom—that is: for defining the architecture. The next chapter builds on it and

explores how specific architectures can be prescribed.

## 4.1 Competitive Strategy

Strategy is about deciding which objectives to pursue—what should the firm aim to excel at, and what shall be dismissed as of secondary importance. In short, strategy is about prioritizing objectives.

### 4.1.1 A Taxonomy of Competitive Strategies

Following Shapiro (1984), we identify three generic competitive strategies that demand different characteristics to the supply chain:

- Competition in Cost
- Competition in Customer Service
- Competition in Innovation

This categorization is satisfactory for a high level description of the strategy: it features relevant dimensions from the standpoint of Supply Chain Management, the dimensions are collectively exhaustive, it is simple, and it is supported by empiric evidence (Miller and Roth, 1994).<sup>1</sup> In addition, if we interpret competition in service and competition in innovation as the only two possible ways of differentiation in supply chain, then this categorization agrees with classic references that identify competition in cost and competition in differentiation as the two main generic competitive strategies (Porter, 1980).<sup>2</sup>

Other categorizations in the literature add quality, speed, and flexibility to the list of potential differentiators (Corbett and Wassenhowe, 1993; Stock et al., 1998). However, it can be argued that these are further sub-categorizations of either service

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<sup>1</sup>Miller and Roth develop a quantitative taxonomy of manufacturing strategies based on cluster analysis of 164 large US manufacturing business units, identifying three statistically significant clusters of competitive strategies: cost, service, and innovation.

<sup>2</sup>Porter actually presents three generic strategies, the third being *focus*; focus can be interpreted, however, as competing either in cost or in differentiation *in a niche*.

or innovation rather than new dimensions. Quality, understood as “delivery conformance,” falls in the category of service; speed, understood as “rapid reposition” is differentiation in service, and understood as “fast product introduction” is differentiation in innovation; flexibility in production volume qualifies as service, whereas flexibility in functionality, or *customization* can qualify either as service or innovation, depending on the context.

### 4.1.2 Strategy and Multiple Objectives

Whether a firm should pursue only one or several objectives at a time is object of an ongoing debate in management literature. Classic references advocate for focused competitive strategies—based either in cost leadership, product differentiation, or entrenchment in a niche (Porter, 1980). Recent works challenge the need for absolute focus on the basis that objectives are not necessarily mutually exclusive in the context of Supply Chain Management: Stock et al. (1998) claim that several objectives can be achieved at a time if the right Supply Chain is in place, McDermott et al. (1997) provide empiric evidence of how commonly accepted tradeoffs no longer hold in the US power tool industry, and Hayes and Pisano (1994) provide a similar analysis of Japanese lean enterprises. Ferdows and Meyer (1990) go further, presenting the argument that quality, dependability, flexibility, and efficiency can all be achieved if they are pursued in this exact order.

Regardless whether only one or several objectives can be attained at a time, the firm must first identify a number of competitive dimensions of interest, and then decide which ones must be optimized, which ones shall be kept on margin, and which ones will be let free. If we call these A, B, and C-class objectives respectively, then a classic approach would choose a single A-class objective, and make all the rest C-class objectives, whereas a more modern approach would allow several A-class objectives.

Our approach will follow the System Architecture heuristic that in general, in any high level system level design it is possible to optimize for an objective, and keep a second objective on range (although suboptimal). Therefore, we will aim for a single objective in each A and B classes.

### 4.1.3 How the Architecture supports the Strategy

Different strategies will demand different properties to the Supply Chain. Competition in cost will demand very efficient supply chains, resilient enough to avoid costly breakdowns. Competition in service will demand the supply chain to be reliable and responsive in order to ensure correct replenishment. Competition in innovation will require a sensitive supply chain that not only delivers the products, but that is also able to feed the design process back with information about what the market demands. Since uncertainty is inherent to new products Fisher (1997), flexibility will be required to produce small batches to test the market, and then scale up the production if necessary, or alternatively kill the product and reallocate resources.<sup>3</sup>

Table 4.1 summarizes the main characteristics that the three generic competitive strategies demand to the supply chain:

<b>Cost</b>	Efficiency
<b>Service</b>	Reliability, Responsiveness
<b>Innovation</b>	Flexibility, Sensitiveness, Adaptability

Table 4.1: Aligning Supply Chain Characteristics and Competitive Strategy

## 4.2 Competitive Environment

Following Fine (2003), we can identify six major environmental forces that shape the supply chain.<sup>4</sup>

- Regulation
- Industry Structure
- Capital Markets

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<sup>3</sup>Adaptability—being able to re-structure the Supply Chain fast is another aspect that we will often see associated to innovation; however, an argument can be made that the need for adaptability does not arise from strategies of innovation themselves, but from certain characteristics of industries where competition in innovation is frequent.

<sup>4</sup>This is commonly known as the “gears” model. Fine actually considers one more force, the corporate strategy.

- Technology Dynamics
- Business Cycles
- Customer Preferences

These forces are dynamic and interrelated—they are in continuous change, and changes in each one influence the others. The Supply Chain Architect must understand not only the impact of each one in the supply chain, but also be aware of their dynamic behavior.

### 4.2.1 Regulation

Regulation limits the feasible design space and can be surprisingly restrictive in a variety of industries. For example, in 40 states in the US it is illegal for automakers to bypass its dealers and sell directly to customers through the Internet (Singleton, 2000). In such conditions, even if the Supply Chain Architect believes that a direct-to-customer approach similar to that of Dell is the right architecture for the downstream fulfillment supply chain, it is pointless to explore this option since regulation would make it impossible.

Cross-national and cross-sector policies limit how logistics can be designed. Zones of free trade, subsidies, tax cuts, and import/export quotas add complexity to the design. Take for example the case of the Manaus Free Trade Zone in Brazil: companies receive tax incentives and reduced import tariffs of components if at least the final assembly of the product takes place in the Manaus Free Trade Zone, which places incentives to companies that need an extensive supply of electronic components such as Siemens, Nokia, or Sagem to push assembly operations to the zone. Unintended consequences can derive from these actions—in 2004 Argentina responded by adopting protectionist measures against imports of TV sets and washing machines manufactured in Manaus.<sup>5</sup>

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<sup>5</sup>Source: “Brazil: Argentina will maintain restrictions on Brazil, says Lavagna,” *Jornal do Comercio*, Nov 4, 2004 (accessed through Factiva, June 10, 2005).

Regulation can have a direct influence on the downstream supply chain; for example, environmental and waste regulation in the EU have resulted in a massive reengineering effort of reverse logistics at Cisco.

Regulation affects upstream as well. More specifically, procurement processes can become extremely complex in presence of stringent regulation. As a consequence of the Buy American Act, providers of the US Department of Homeland Security are expected to use at least 50% US-manufactured components, putting enormous stress on the supply chains of providers of electronics items such as cell phones, which cast doubt on whether it will even be feasible to achieve such figures.<sup>6</sup>

If *existent* regulation conditions the actual design of the supply chain, the relative *stability* of the regulatory environment places a premium on adaptability—on being able to change the structure of the Supply Chain with minor disruptions to operations and cost structures.

## 4.2.2 Industry Structure

Industry structure, and the firm's position in the Supply Chain (upstream, downstream, midstream) condition design options such as supply chain integration, outsourcing agreements, or distribution network design. Important questions to be answered are: Does the industry structure favor vertical or horizontal competition? How likely is this to change? In what time horizon? How fast? Is production global or local? Consolidated or Fragmented? What is the role of channel intermediaries?

Industry integration makes possible integral Supply Chains, while disintegration favors modular products and Supply Chains. Integration-disintegration cycles may exist,<sup>7</sup> and the transitions impose profound structural changes in the supply chain.

Take for example the consumer goods market. Can Procter & Gamble or Unilever ignore Wal-Mart's role in the distribution market? Of course not. One player in the

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<sup>6</sup>Source: Ed Frauenheim. 'Buy American' Legislation Draws Fire. C!NET News, May 20, 2005. URL [http://news.com.com/Buy+American+legislation+draws+fire/2100-1022\\_3-5715486.html?tag=nefd.top](http://news.com.com/Buy+American+legislation+draws+fire/2100-1022_3-5715486.html?tag=nefd.top)

<sup>7</sup>Fine (1998) proposes a conceptual model, the *Double Helix*, to analyze integration and disintegration cycles

downstream supply chain has grown so powerful that upstream providers are fully dependent on it. In situations like this, it is pointless to even consider direct-to-customer models or forward integration as potential design degrees of freedom. This is what we call the risk of intermediation. Counterintuitive supply chain strategic agreements can arise from these situations, such as P&G’s generous VMI agreements with HEB, arguably developed to weaken Wal-Mart’s bargaining power with P&G.<sup>8</sup>

Disintermediation is also possible. Fine (1998) presents the cases of Intel’s “Intel Inside” campaign, or Shimano equipment in bicycles as notable examples. Intermediation and disintermediation change the sources of power and, with them, the structure of the supply chain and the performance drivers.

Finally, globalization is unavoidable in some industries such as apparel or electronics, and production far from the target markets adds the challenge of longer lead times to the problem of designing the supply chain.

### **4.2.3 Capital Markets**

Capital markets set the time horizon for the firm’s results—demanding short or long-term results, and determine whether it is possible or not for the firm to make capital investments, which ultimately determines the growth and operations strategies of the firm.

### **4.2.4 Technology Dynamics**

New technologies enable new supply chain architectures. Virtually Integrated supply chains (like Dell’s), collaborative planning, replenishment and forecasting strategies were hardly possible before the introduction of modern data communications, and more specifically, the Internet.

Improvements in the manufacturing process remove burden from the supply chain (e.g. lessening the need for high-scale reverse logistics), but as production constraints are removed, additional stress is placed in the supply chain not to become the next

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<sup>8</sup>See for example Austin and McFarlan (2001); McFarlan and Dailey (2003).

bottleneck. For example, as new manufacturing technologies enable more flexible production, the supply chain needs to respond with equally flexible logistics.

#### **4.2.5 Business Dynamics**

Does the industry exhibit cyclical behavior? Is cyclicity externally or internally triggered? – that is: is such behavior a consequence of correlation with some external factor such as oil prices or changes in the GDP, or does it respond to an internal property of the system, such as the Bullwhip Effect? (Forrester, 1961; Chen et al., 2000; Simchi-Levi et al., 2003; Lee et al., 1997).

Industries with tendency toward large Bullwhip waves may endanger the survival of providers upstream, which will hit back the downstream supply chain as upstream providers consolidate or even disappear. Anderson et al. (1999) present evidence of this phenomenon in the automotive machining tool industry. If a long-term resilient supply chain is going to be designed to operate in an environment like this one, supplier contracts will play an important role—close supplier relationships that ensure acyclical orders, long-term partnerships, non-exclusive contracts, and balanced portfolios of customers will be determinant.

#### **4.2.6 Customer Preferences**

Are customer preferences stable and predictable, or on the contrary, are they volatile and unpredictable? What does the customer value? High product customization? Product variety for the sake of variety? Fast product renewal rate? How often customer priorities change? Volatile demand will favor responsiveness and flexibility and certain types of supply contracts. Fast-evolving customer preferences in the fashion industry favors sensitive, demand-driven supply able to feed demand information directly into the design process. Demand for customization and product variety in the PC industry benefited from component standardization and product modularity.<sup>9</sup>

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<sup>9</sup>In addition, product modularity can also benefit product introduction rate, because it decouples the evolution rate of the components from the evolution of the product itself, allowing the product to benefit from newer generations of components.



Changes in customer preferences and priorities made possible for Amazon to sell apparel and beauty products from the Internet, and made a success out of Ikea's unusual supply chain—furniture is no longer an investment for life and therefore customers are less sensitive to durability, and more to cost.

We will find other provider/customer relations all along the supply chain. The issues will be different from those posed by the end customer, but the main question remains the same: what does the customer really value, and for how long?

### **4.3 Internal Capabilities and Constraints**

The competitive environment sets constraints that are common to all the players in a certain industry operating in a specific geographic region. However, every single firm faces also constraints and opportunities consequence of the firm's specific capabilities and limitations.

These capabilities and constraints can be systematically explored in the light of the L-model by studying independently the Product Development Supply Chain, the upstream fulfillment supply chain (the Production System), and the downstream fulfillment supply chain (the Distribution System).

Questions relevant in this aspect are – are the customers loyal, so that service levels can be lowered without revenue losses? Are the product margins high? Is production flexible? Does the firm have significant economies of scale and scope? Does the firm have easy access to capital?

### **4.4 The Design Process**

We propose a design process composed of the following steps:

1. Identify the feasible supply chain design degrees of freedom
  - (a) Use Fine's "gears" model to systematically analyze and understand the environmental constraints.

- (b) Use the proposed L-Model to pinpoint and understand internal constraints and capabilities.
- 2. Identify the strategic dimensions of the supply chain—what the supply chain needs to support the business strategy—and formulate objectives.
- 3. Assess the influence of design degrees of freedom in the desired outcome and the interactions between design parameters.
- 4. Take specific decisions over these design degrees of freedom.

This chapter has addressed the first two points. Figure 4-1 summarizes the process, illustrates some of the factors that must be assessed, and provides a non-exhaustive list of the different degrees of freedom that the architect may consider. The next chapter will address the remaining two.

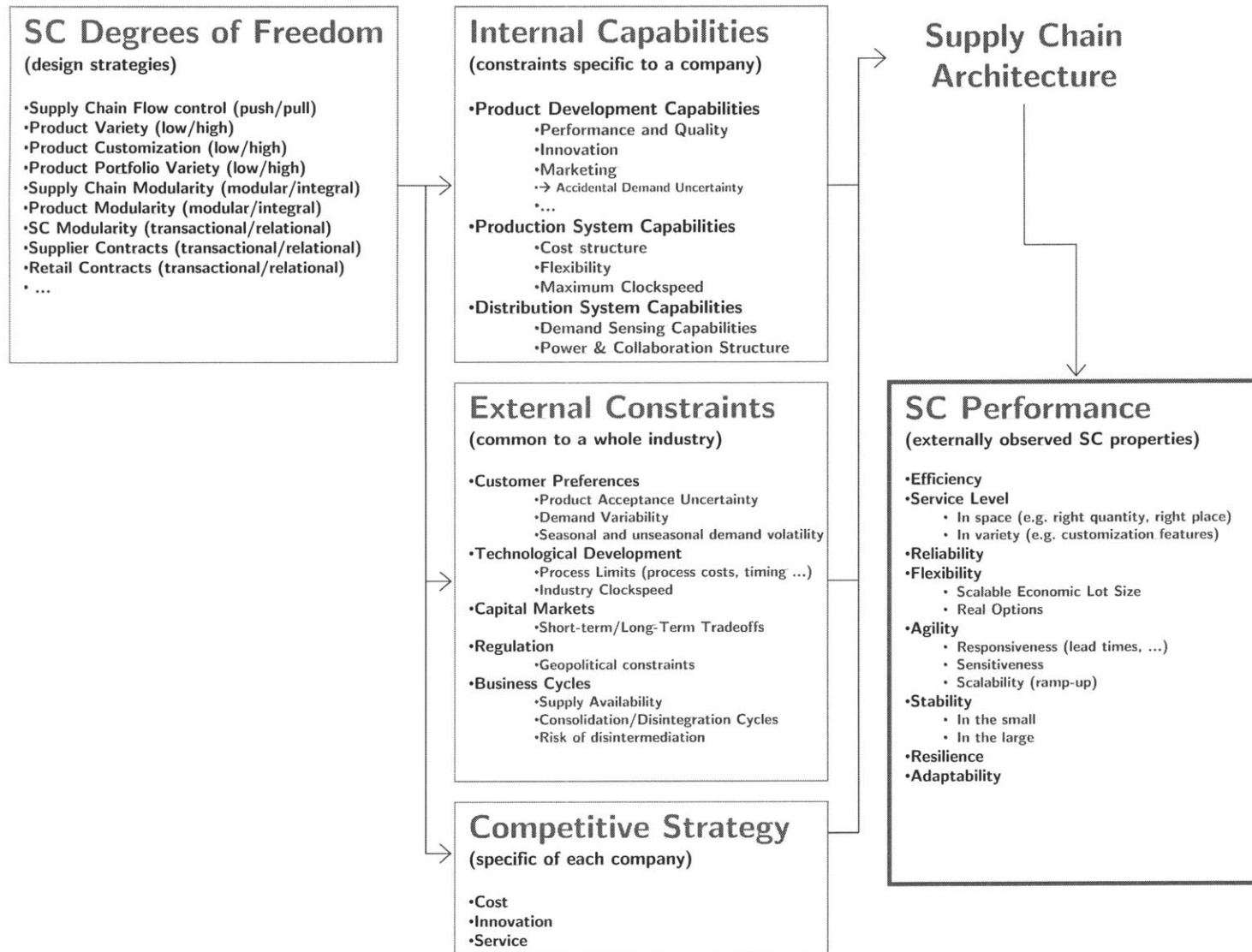


Figure 4-1: The Design Process



# Chapter 5

## Prescribing Supply Chain Architecture

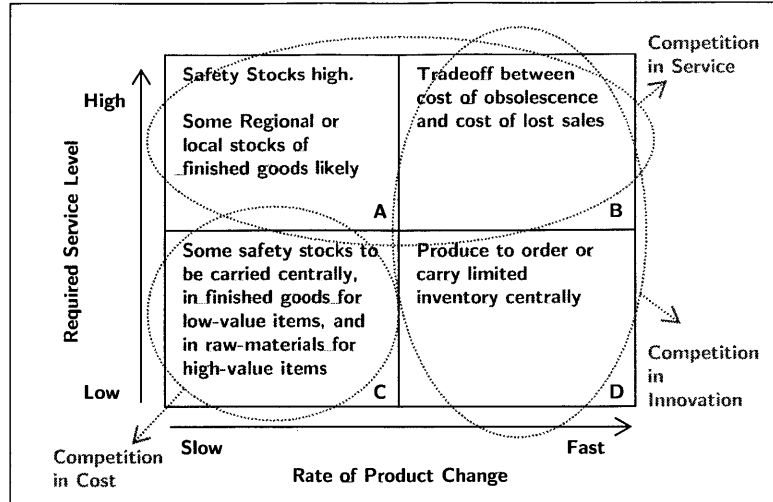
In chapter 4 we proposed a method for the systematic analysis of objectives, capabilities, and constraints of a supply chain—the first step in architecting a supply chain. This chapter explores the second part of the design process: *prescribing* a supply chain architecture based on the analysis.

A number of frameworks for taking such supply chain design decisions have been described in the literature. Most of them characterize the environment in terms of a reduced number of variables (typically only two) and provide a prescription for a limited number of degrees of freedom (typically one). While limited, these frameworks are valuable for two reasons:

1. They identify relevant design degrees of freedom
2. They isolate the most relevant variables that drive the design decision on these degrees of freedom

This chapter explores a number of these frameworks, and synthesizes an integrative framework for taking decisions on five specific degrees of freedom in different parts in the L-Model:

1. Flow Control Strategy



Adapted from Shapiro (1984). The regions of competition in innovation, service, and cost have been marked with ellipses.

Figure 5-1: Inventory policy as a function of Clockspeed and Service Level

2. Product Variety
3. Product Modularity
4. Supply Chain Modularity
5. Product Introduction Rate

## 5.1 Review of Frameworks

### 5.1.1 Matching Supply Chain and Strategy

Shapiro (1984) proposes a framework to assess the right inventory policy in terms of the desired service level<sup>1</sup> and the speed of product change. The tuple  $\{\text{service level}, \text{rate of product change}\}$  can be interpreted in terms of the three base competitive strategies described in the previous chapter.

In general, all other factors being equal, it is safer to build stock when the rate of product change is slow (since obsolescence risk is low), and it is better to place inventory buffers closer to end demand if high service levels are to be offered. This

<sup>1</sup>Shapiro actually uses the term “competitive intensity” to refer to greater service levels.

results in four possible regions, labeled (A), (B), (C), and (D) in the diagram. In (A) we find products such as pasta or canned tuna. There is no risk of obsolescence, so inventory can be built; a high service level is expected, so that this inventory must be placed close to the end demand (the longer the lead times, the closer).

As we lessen the requirements for the target service level, we fall into (C): now it is possible to centralize inventory and pool demand to attain greater efficiencies. (D) represents the case of manufacturers that build or assemble to order, hence operating with a service level close to 0%, such as Dell. To a lesser extent this would also be the case of Zara, which actually does not aim for high service levels. As the required service level increases, we move into the “newsvendor” quadrant (B), where it becomes less clear what is the best strategy to handle inventory, and a detailed analysis must be performed.

A second framework (see Figure 5-2) assesses which part of the supply chain bears most of the costs—upstream as production costs, or downstream as inventory<sup>2</sup>—in terms of product variety offered to the end customer and how inventory is carried along the supply chain.<sup>3</sup> Inventory costs increase with inventory decentralization (as a consequence of reduced risk pooling), and production costs increase with variety.

It is important to note that, all factors being equal, the demand variability observed at the edges of the distribution network (e.g. at retail stores) will increase if product variety increases. How much will it impact inventory costs depends on the characteristics of the product and the location of the point where demand is pooled. For example, if demand is pooled at a central distribution center upstream and product variety increases, *observed demand variability* at the inventory stocking point won’t change that much. In conclusion, inventory costs in the quadrant with decentralization and great variety (B) will be higher than those in quadrant (A). Inventory costs in quadrant (D) will also be higher than those in quadrant (C), but in

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<sup>2</sup>Inventory holding costs, product markdowns, and salvage costs are among the factors that contribute to a kind of Supply Chain costs that we will call Market Mediation costs.

<sup>3</sup>Shapiro refers to this as the “degree of speculation” of the network, which ranges from not carrying inventory at all, to carrying inventory of finished goods at local warehouses close to end demand; this concept is closely related to the what we will call the *push-pull boundary* (Simchi-Levi et al., 2004, pag. 96) which we will introduce in section 5.1.5 on page 65

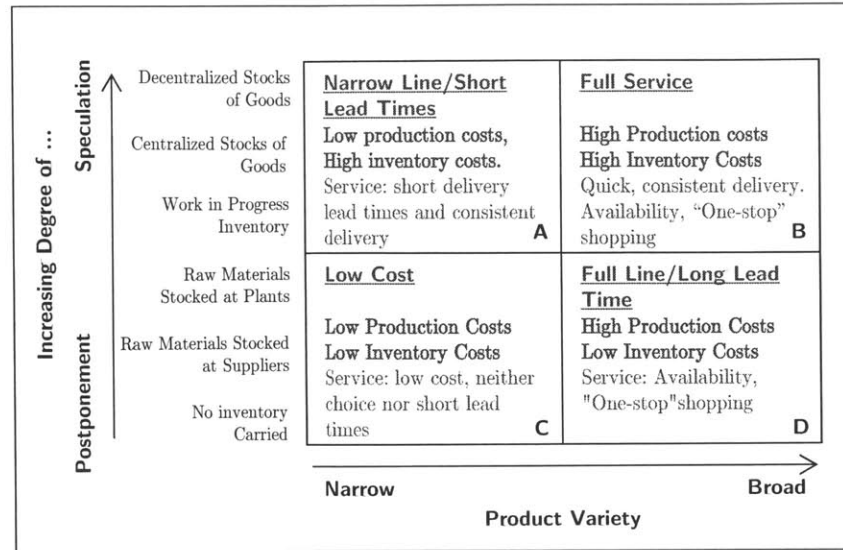


Figure 5-2: Part of the Supply Chain that bears the costs as a function Product Variety and Centralization (Shapiro, 1984)

general the difference won't be as strong as in the change from (A) to (B).

### 5.1.2 Matching Supply Chain and Product

Fisher (1997) observed that product life cycle, demand predictability, target service level and other important factors in supply chain design are largely determined by the type of product that flows through the supply chain, and therefore different types of products benefit from different types of supply chains.

*Functional products*, those that satisfy basic needs such as canned food or milk, tend to have stable demand and longer life cycles because basic human needs do not change much over time; they also tend to exhibit lower margins. In consequence, functional products benefit from cost-efficient supply chains that do not erode the tight margins these products usually have. If a high service level is needed, safety stocks can be safely built since there is little risk of obsolescence.

*Innovative products*, those that seek to differentiate through new, distinctive features (innovations), such as cell phones or game consoles, tend to have less predictable demand, greater margins, and shorter life cycles—usually determined by the speed of imitation of competitors. The risk of inventory obsolescence is high, and since



margins are high and lifecycle short, the cost of stockouts is equally high. For these reasons, innovative products require responsive supply chains capable of fulfilling all the demand while keeping safety stocks low.

Table 5.1 summarizes the main characteristics of functional and innovative products.

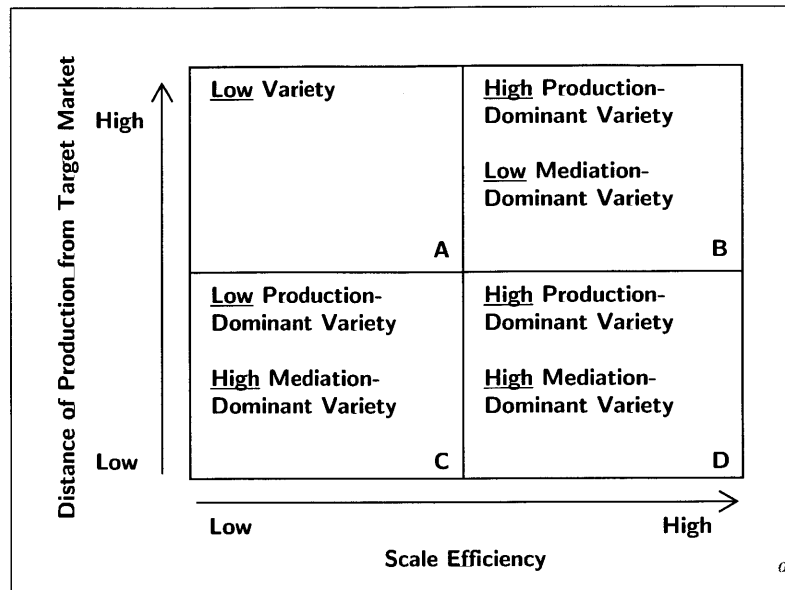
Aspects of Demand	Functional	Innovative
Product Life Cycle	more than 2 years	3 months to 1 year
Contribution Margin	5% to 20%	20% to 60%
Product Variety	low (10 to 20 variants per category)	high (often millions of variants per category)
Average margin of error in the forecast at the time production is omitted	10%	40% to 100%
Average Stockout Rate	1% to 2%	10% to 40%
Average forced end-of-season markdown as percentage of full price	0%	10% to 25%
Lead time for made-to-order products	6 months to 1 year	1 day to 2 weeks

Table 5.1: Differences in Demand of Functional vs. Innovative Products (Fisher, 1997)

According to Fisher, products that are physically the same can be either functional or innovative—the difference is just how they were marketed: for example, high-tech razor blades or premium ice cream are examples of functional products that have been marketed as innovative products.

### 5.1.3 Matching Supply Chain and Product Variety

Randall and Ulrich (2001) build on the idea that a Supply Chain has a physical function (enabling the transformation of raw materials into finished goods) and a market mediation function (deliver the right amount of finished goods to the right place at the right time) (Fisher, 1997), and classify variety in two broad categories *production-dominant variety* and *mediation-dominant variety*.

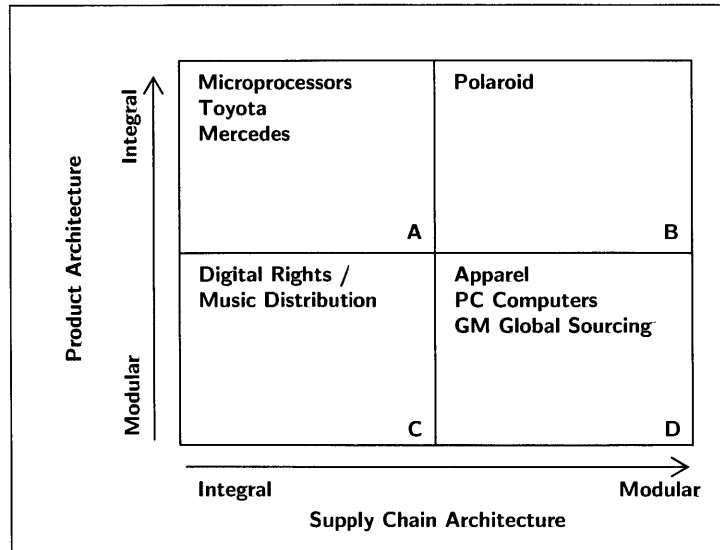


<sup>a</sup>Source: adapted from Randall and Ulrich (2001). Randall and Ulrich call the A quadrant a “dominated strategy,” because it will only exist if no other possibility is available; in a similar way, quadrant D is called a “dominant strategy” because if it feasible, it will be preferred to any other.

Figure 5-3: Matching Variety with Supply Chain Structure

*Production-dominant variety* increases the cost of the physical function, whereas *Mediation-dominant variety* increases the costs of the market mediation function. As an example, different engines or transmissions offered as options in a car are production-dominant, while different colors are mediation-dominant: from the standpoint of the market, a choice of an additional transmission is not different than an additional color—yet another option for the customer to choose, and yet another potential mismatch between what sits at the dealer’s parking lot and what the customer really wanted. From the standpoint of manufacturing, however, adding one additional color costs little (provided that there is space for one more color in the palettes of the painting robots), but adding one more transmission involves a substantial engineering and procurement effort, not to mention that the complexity of the production system will increase.

Randall and Ulrich propose that supply chain structure must match the type of variety offered (see Figure 5-3), and provide empiric evidence from the US bicycle industry that firms that align production-dominant variety with scale-efficient pro-



Source: Adapted from Fine and Whitney (1996) and Fine (1998, pag. 169)

Figure 5-4: Matching Variety with Supply Chain Structure

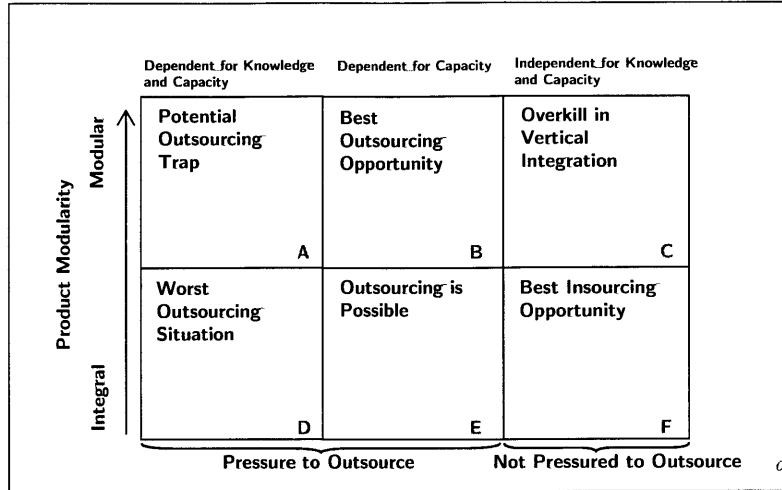
duction and mediation-dominant production with local production outperform those that don't align it.

#### 5.1.4 Supply Chain, Sourcing and Product Architecture

Fine (1998) introduces the term “Clockspeed” to denote the pace of an industry—the rate at which new products are introduced and technologies evolve. Clockspeed tends to slow down as we move upstream in the Supply Chain,<sup>4</sup> with important implications for business cycles—Anderson et al. (1999) provide evidence that clockspeed slowdown, combined with increased volatility due to the bullwhip effect, is the underlying cause of cyclic crises in certain industries, such as the automobile machining tool. As a result, industries upstream face bigger and longer peaks and depressions. As depressions become stronger, more companies fail to survive—and upstream industry tends to consolidate if countercyclical markets are not available.

Fine proposes an alternative model for aligning Supply Chain, Sourcing and Prod-

<sup>4</sup>Situations exist where the components evolve faster than the finished product—such as in personal computers, but on the other hand every time components are updated can be considered a new product release.



<sup>a</sup>Source: adapted from Fine and Whitney (1996), Fine (1998, pag. 170) suggests that technology clockspeed and density of supplier base must be also considered in the framework; slow clockspeed and many possible providers reinforces the case for outsourcing, while fast clockspeed and few providers make it more difficult.

Figure 5-5: Matching Component Modularity and Sourcing Strategy

uct Architecture based on the concept of supply chain modularity. Fine classifies both Product and Supply Chain Architectures in two categories: modular and integral. Integral products are those whose elements perform many functions, are in close spacial proximity, and are tightly synchronized. Modular products feature elements that are interchangeable, individually upgradeable, and connect through standardized interfaces. The same analogy holds for value chains—integral supply chains are tightly coupled geographically, organizationally, culturally, and in information exchange. According to Fine, mismatches will occur when a modular product uses an integral supply chain, or when an modular supply chain is used with an integral product.

Product modularity has also important implications for sourcing policies (Fine and Whitney, 1996; Fine, 1998): the parts of modular products are easier to outsource, but also make easier for the outsourcers to supplant the firm—after all, they have access to the same components, and when outsourcing is done because the firm lacks domain knowledge, outsourcers will also be better integrating the different modules.

### 5.1.5 Push and Pull Supply Chains

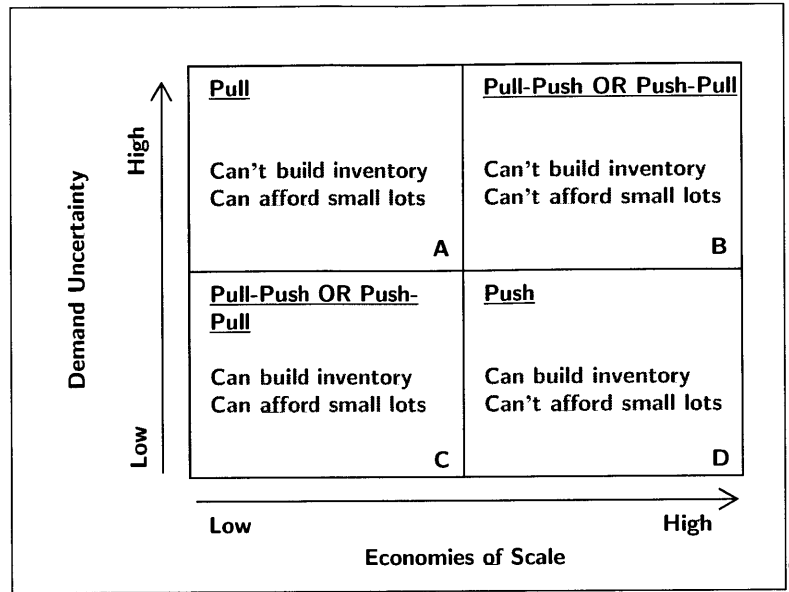
Simchi-Levi et al. (2003, 2004) focus on how the flow of goods is coordinated along the supply chain. They distinguish between supply chains where the flow is triggered by actual demand signals, or *pull-based* Supply Chains, supply chains where the flow is triggered by a forecast of future demand, or *push-based* Supply Chains, and hybrid approaches.

*Push* supply chains can plan capacity utilization in advance and hold shipments until economic lot sizes are achieved, all at the expense of longer lead times and poor responsiveness to demand fluctuations. Safety stocks must be used to compensate the lack of responsiveness if a certain service level is required.

*Pull* supply chains are less efficient, but exhibit shorter and less variable lead times, which results in lower safety stocks needed for the same service level.

In hybrid *push-pull* or *pull-push* strategies one part of the supply chain is managed as push-based supply chain, and the other as a pull-based supply chain. The point where both chains converge is called the *push-pull boundary*. Push-pull takes advantage of risk pooling upstream to produce according to a forecast and keep efficiencies high, while preserving responsiveness downstream. Pull-push batches deliveries for efficient delivery, while holds supply provisioning until demand uncertainty has been revealed. This works particularly well in cases where internal variety is too large to build stock of components and raw material safely, and cost-efficient transportation is needed, such as in the case of certain types of furniture (Simchi-Levi et al., 2003, pag. 125). In these cases, furniture is made to order, and materials are procured through a pull-based supply chain. Finished goods are delivered using a push-based supply chain since they are bulky pieces that need cost-efficient transportation.

Simchi-Levi et al. (2003, pag. 124) propose a framework for matching the right strategy with product characteristics (Figure 5.1.5). Quadrants (A) and (D) have dominant concerns—managing demand uncertainty in (A), achieving economies of scale in (D), and therefore demand “pure” strategies: (A) demands pull-based, responsive supply chains; (D) demands push-based, efficient supply chains. A more



<sup>a</sup>Source: Adapted from Simchi-Levi et al. (2003, pag. 124).

Figure 5-6: Matching Supply Chain flow control and Product

detailed analysis is needed in quadrants (B) and (C), but in general they will demand a hybrid strategy.

A similar framework is provided by Christopher (2000), who proposes that in conditions of scale insensitivity and high demand uncertainty/variety, an agile supply chain must be used, whereas more predictable environments that need high production volumes favor lean supply chains.

## 5.2 Discussion

Fisher (1997) shows how correlation among the different input variables can simplify the decision-making process: because demand uncertainty *and* margins tend to increase with product novelty, a simple categorization of products in two types can provide a prescription about supply chain structure general enough to accommodate a wide variety of cases. In the same way, this section attempts to isolate key factors to be considered and the inter-relationships between them in order to provide a decision framework.

### 5.2.1 Important Factors to be Considered

In general, five key variables underlie all the frameworks presented: demand risk, clockspeed, lead times (distance to market), economies of scale (need for volume), and product/process architecture (modularity, commonality, standardization...).

#### Demand Uncertainty

Demand uncertainty refers to how difficult it is to forecast demand—not just how *variable* the demand is. The distinction is subtle: highly seasonal demand has high variability, but not necessarily high uncertainty. The opposite also holds: demand for a new product can be very stable once it materializes, but be highly uncertain during the product launch.

Demand uncertainty determines the level of safety stocks that are necessary to provide a certain service level, or, alternatively, how fast lead times must be in order to ensure on-time replenishment. It is therefore deeply and directly related to the cost structure of the supply chain.

Following the nomenclature proposed by Christopher and Towill (2001), we can identify two components of demand uncertainty;

- *Base* demand uncertainty, or the maximum level  $Q$  of safety stock that can be produced in advance, such that the probability that actual demand won't exceed  $Q$  is greater than a certain quantity  $\alpha$ .<sup>5</sup> Base demand will be the major concern for innovative products.
- *Surge* demand is the “noise” on top of the base demand. Surge demand will be the dominant concern for functional products.

Metrics that attempt to measure demand uncertainty based on simple descriptive statistics of the demand process, such as the coefficient of variation (standard deviation divided by the mean,  $\sigma/\mu$ ), have the problem of measuring *demand variability*, not *demand uncertainty*.

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<sup>5</sup>Note that predictable seasonality is included in the calculation.

The surge/base demand ratio can be considered a better estimator of demand uncertainty than metrics such as the coefficient of variation, because it takes into consideration the firm's forecasting capabilities. For example, a highly seasonal product will exhibit a high coefficient of variation, yet be very predictable, and therefore it will exhibit a very low surge/base ratio. Replacing “variability” by “predictability” has the additional advantage that now the nature of the product is fully considered—all other factors being equal, the surge/base demand ratio will be high for products marketed as *innovative*, and low for products marketed as *functional*.

Surge and base demand depend on how good our forecasting capabilities are, which it is in turn closely related to how effectively the firm is able to sense the end demand and share this information across the supply chain. Two other factors that influence surge and base demand are product positioning (i.e., is the product functional or innovative?), and the method of risk pooling in use (e.g. the in space across different geographic regions, aggregation in time through longer planning periods, aggregation in products through product variety reduction, or aggregation in component through product modularity and component and process standardization.)

## **Clockspeed**

Clockspeed, understood as the pace of change of products, determines the risk of inventory obsolescence. A possible metric for clockspeed is the average number of non-trivial product changes (those that require physical changes in the supply chain) per product per year.

Clockspeed acts as a multiplier of the cost of safety stocks and shifts design priorities—the faster the clockspeed, the greater the risk of inventory obsolescence, and therefore, the more important it is to be able to keep inventories low. For these reasons, in general, higher clockspeeds will put stress on push-based supply chains, since push batching tends to generate large quantities of work in progress and finished inventory. But push-based supply chains are also inappropriate in fast clockspeed environments because excess inventory must be either cleared out either by delaying new product launches, or by issuing discounts to get rid of old inventory—a costly



solution in any case.

Product modularity and component standardization and sharing across a product family can mitigate the impact of clockspeed, as it decouples component obsolescence from product obsolescence. But in order to take full advantage of it, an hybrid, push-pull supply chain is needed, where components upstream are replenished according to a forecast, and distribution downstream is driven by demand to keep inventories low.

## Lead Times

Lead times, understood as the cycle time to serve a new order from scratch, limit the feasibility of pure pull-based supply chains, multiply the impact of eventual disruptions—leaving little room for reaction in case something goes wrong, and amplify demand volatility along the supply chain. We will call “velocity” to the inverse of the lead times (e.g, high velocity will therefore mean short lead times).

Service levels and network structure are indirectly affected by lead times. With long lead times, it will be necessary to allocate additional safety stocks to account not only for the demand uncertainty, but also for the replenishment process. Long lead times will also favor sparse distribution networks.

Lower lead times make possible to either increase the service level with the same amount of safety stock or the same network sparseness, or to maintain the same service level with less safety stock, or a more centralized network.

However, it is important to realize that service levels and lead times are two different aspects of quality of service that must be handled in different ways. Service level is more stringent than lead times—it is about how likely it is that the lead time will be 0, that the customer will find the product needed *in stock*. Therefore, it can only be managed through safety stocks. In contrast, quality of service based on lead times commitments accept a wider variety of solutions.

## **Economies of Scale**

Economies of scale can be measured in terms of the minimum economic lot size for production and transportation. The need to reach larger lot sizes favors efficient, push-based supply chains, with batched production and distribution, centralization of production capacity. It places incentives to integrate and grow in scale.

From the point of view of strategy, economies of scale raise barriers to entry to competitors, and barriers to exit to the firm—once capacity has been built to reach scale, it is difficult to downsize it. The search for higher economies of scales therefore can reduce the speed of adaptation of the firm.

In global markets, economies of scale push for centralizing production far from the target markets, increasing lead times. In these circumstances, a reliable the Supply Chain is needed to keep mediation costs on target.

We will call “flexibility” to the absence of significant economies of scale—that is, to the capability of producing batches of arbitrary sizes efficiently.

## **Product and Process Modularity**

One of the conclusions from previous frameworks is that product, production process, and supply chain must be considered jointly. Integral products need integral Supply Chains, and modular products benefit from modular supply chains.

Modular designs allow to postpone mediation-dominant variety as much as possible, enabling hybrid push-pull supply chains. More modular products allow to place the push-pull boundary as upstream as the lead times permit.

Production-dominant variety can’t easily be postponed, so that products with essentially different types of variety will need to be addressed with different supply chains. However, these supply chains can share certain common parts, which ultimately leads to the concept of supply chain modularity, as a response of how can we have a supply chain tailored to the needs of each product while keeping cost and complexity on target.

A simple metric for assessing commonality and modularity can be built by taking

the difference of the logarithms of external and internal variety. That is, given a number  $M$  of different end product configurations, made out of a total of  $N$  different components in the assembly line, modularity can be assessed as  $\log(M) - \log(N)$ .<sup>6</sup>

## 5.2.2 Architecture as a way of decoupling tradeoffs

The previous section introduced a number of cases where an apparent tradeoff between factors was weakened via a change in supply chain or product architecture—for example, more modular products and a hybrid push-pull strategy make possible to increase external variety without major impact on inventory costs. When this happens, we say that the architecture has *decoupled* two variables.

Several other tradeoffs exist. A non exhaustive list follows:

- $\uparrow$  Service Level  $\Rightarrow \uparrow$  Safety Stocks  $\Rightarrow \uparrow$  Inventory Costs
- $\uparrow$  Clockspeed  $\Rightarrow \uparrow$  Inventory Obsolescence Rate  $\Rightarrow \uparrow$  Inventory Risk
- $\uparrow$  Variety  $\Rightarrow \uparrow$  Observed Demand Variability at the Sales Point
- $\uparrow$  Network Decentralization  $\Rightarrow \uparrow$  Observed Demand Variability at the Stock Point  $\Rightarrow \uparrow$  Inventory Costs
- $\uparrow$  Product Innovation  $\Rightarrow \downarrow$  Demand Predictability,  $\downarrow$  Product Life Cycles,  $\uparrow$  Margins  $\Rightarrow \uparrow$  Pressure to improve Supply chain Responsiveness
- $\uparrow$  Distance from Manufacturing to Market  $\Rightarrow \uparrow$  Cost of market mediation  $\Rightarrow \uparrow$  Pressure to reduce mediation-dominant variety  $\downarrow$  Scale-Efficiency Achieved in Production  $\Rightarrow \uparrow$  Cost of production  $\Rightarrow \uparrow$  Pressure to reduce production-dominant variety

In all these cases, it is also possible to decouple the effect of variables on the left-hand side on the variables on the right-hand side by altering the architecture. Some examples follow:

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<sup>6</sup>This metric is based on the concept of *variety* and variety gains. Entropy-based measures can also be used, taking the difference of the entropy of the output configurations and the input components, where the entropy of each is calculated as  $H(X) = \sum_{i=0}^N p_i \log(\frac{1}{p_i})$ , where  $p_i$  is the likelihood of a certain configuration or component.

- Moving the Push/Pull Boundary. A supply chain can be split in two regions, one driven by a forecast, and another driven by demand, so that one part of the supply chain can concentrate in minimizing inventory (the pull part), and the the other part can concentrate in being efficient (the push part).
- Commonality. Components of a product can be standardized and pooled across families of products, so that product obsolescence can be decoupled component obsolescence (e.g. hard drives and PC computers), and economies of scale can be achieved even for products with limited volume.
- Virtual Integration. Information from sales downstream can be fed back in real time upstream without the need for actual control of the whole supply chain (vertical integration).
- Product Modularity. A product can be designed in a way that the final product is obtained by combination of different modules, so that product variety is increased without substantially increasing the observed demand variability at the stock point.
- Spatial Risk pooling. Intermediate distribution centers can be placed strategically across a geography in order to pool demand and reduce replenishment lead times, so that service level can be increased with little impact on safety stocks.
- Delayed Differentiation. The final part of the production process can be postponed.
- Channel Split. Different supply chains can be used to handle product families with fundamentally different demand patterns.
- Surge/Base Split (Fisher et al., 1994; Christopher and Towill, 2001). Two different supply chains are can be used to handle a certain minimum expected base demand, typically an efficient, push-based supply chain, and a different supply

chain can be used to address the demand uncertainty over the base demand (typically a responsive, pull-based supply chain).

Other patterns are possible, as well as combinations of the previous ones. Decoupling variables, though, comes at the expense of increasing the complexity of the architecture, and with it, the difficulty of implementation and operation.

### 5.2.3 Putting Everything together

Figure 5-7 provides a categorization of four different supply chain design paradigms in terms of the environment clockspeed and the demand uncertainty (which can be also used as proxies for the strategy, see Figure 5-1):

**Mass Production** represents the classic batch production, bulk transportation company; it is optimized to be as efficient as possible in production costs, at the cost of poor market mediation capabilities. This is a suitable model for slow-moving products with predictable demand such as bulk sugar.

**Lean** focus on minimizing waste, and trades production cost for demand risk efficiently—that is: while a lean supply chain will have higher production and supply chain costs than a mass production company,<sup>7</sup> but risk of over/under production (that is, the market mediation costs) that as demand becomes more uncertain and inventory more costly, the overall profit balance will favor lean.

**Adaptive** focus on managing existing capacity and steering the demand.

**Agile** is about fast demand sensing and fast response to changes in customer's preferences. It makes sense when there is a high inventory risk due to inventory obsolescence, and customer preferences change all the time, so that forecasts are not trustworthy and safety stock too expensive; in these cases the best that can be done is to just follow the demand as fast as possible.

Figure 5-8 updates Simchi-Levi et al.'s framework presented in Figure 5.1.5 to include the effect of the different key factors studied in previous section.

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<sup>7</sup>Unless flexible manufacturing and logistics are available.

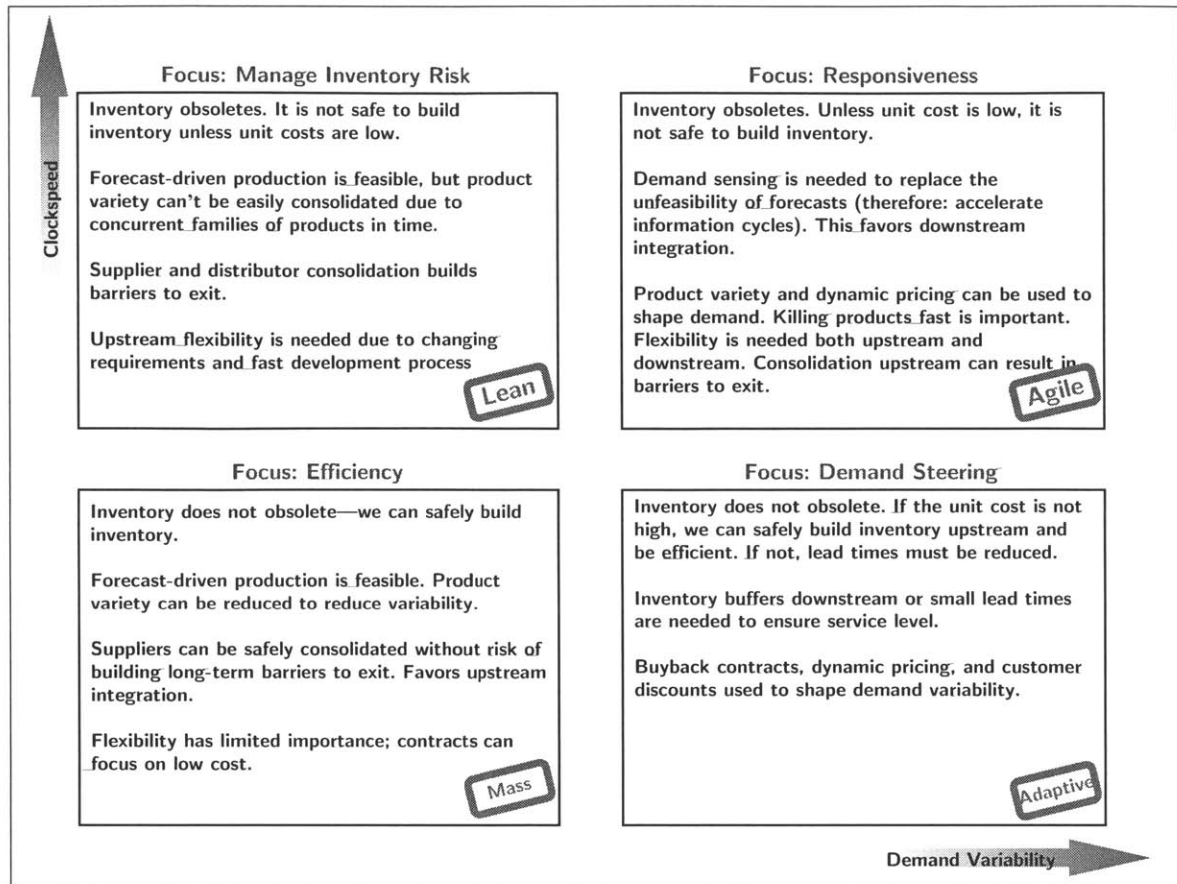


Figure 5-7: A categorization of Supply Chain Strategic Focus

Figure 5-9 presents an alternative representation of the framework, detailing objectives, rationale, and assumptions.

Figure 5-10 presents in the same format the decision process for product introduction rate, variety, and modularity.

Figure 5-11 summarizes the previous figures and depicts a simple framework for matching supply chain focus, supply chain and product characteristics.

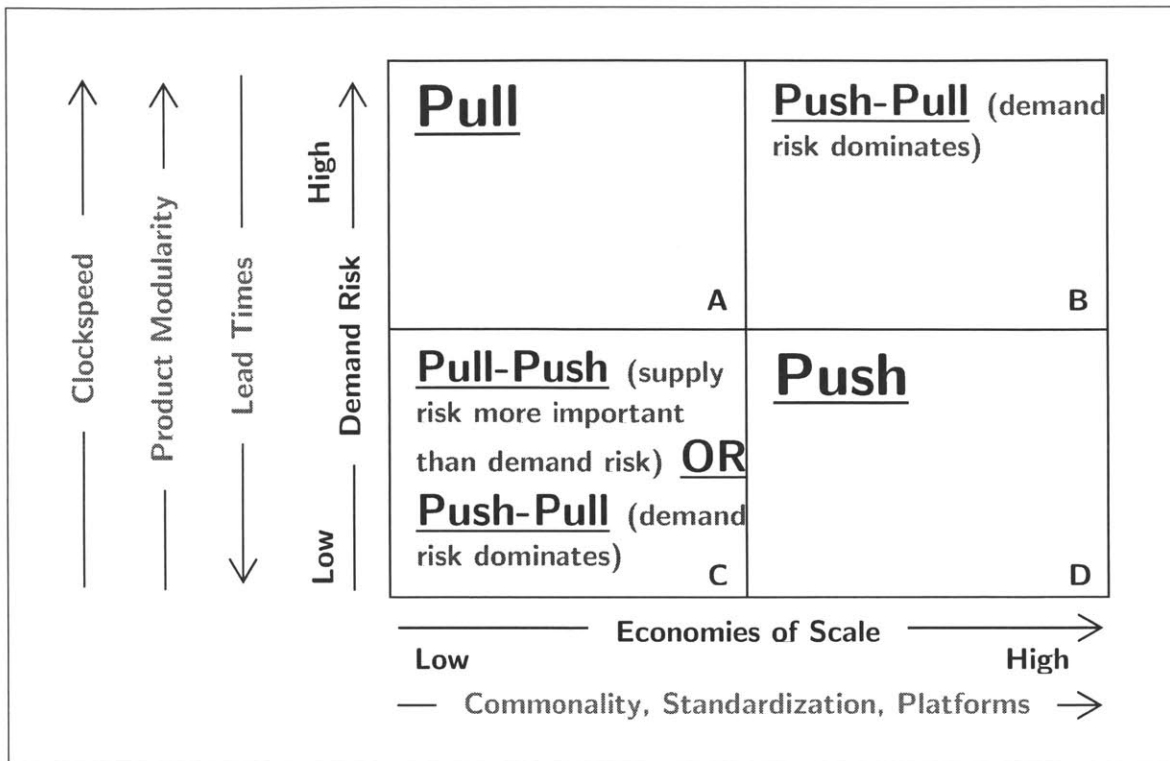


Figure 5-8: When to use push, pull, and hybrid strategies

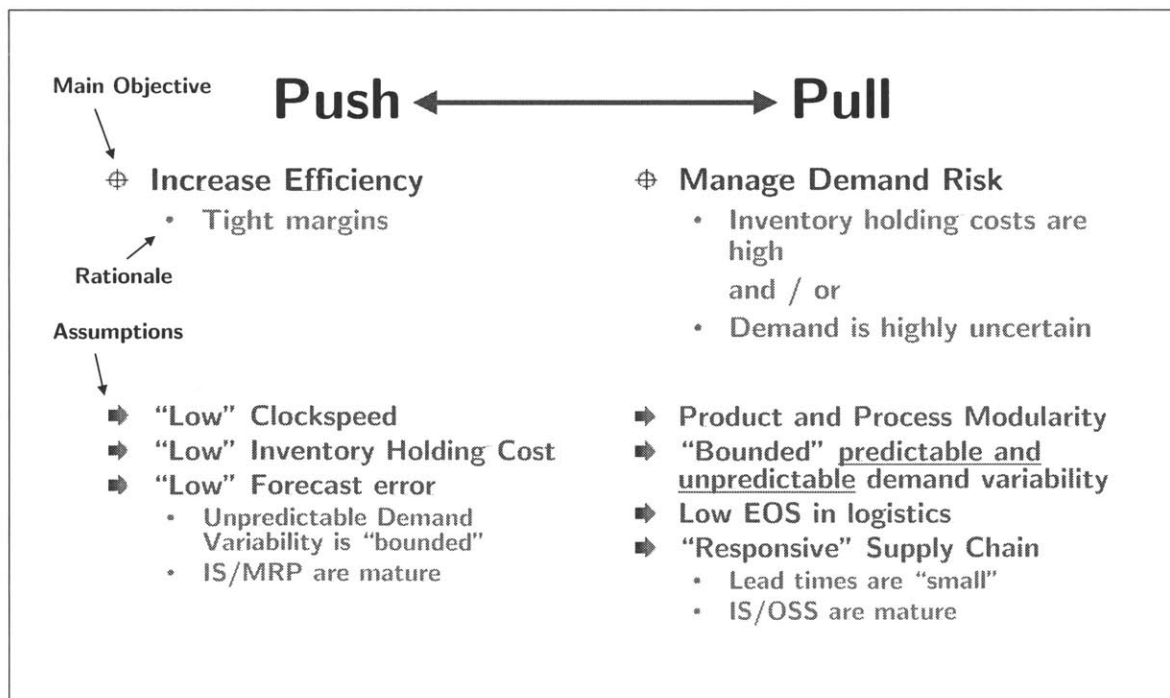


Figure 5-9: When to use push, pull, and hybrid strategies—A pattern language approach.

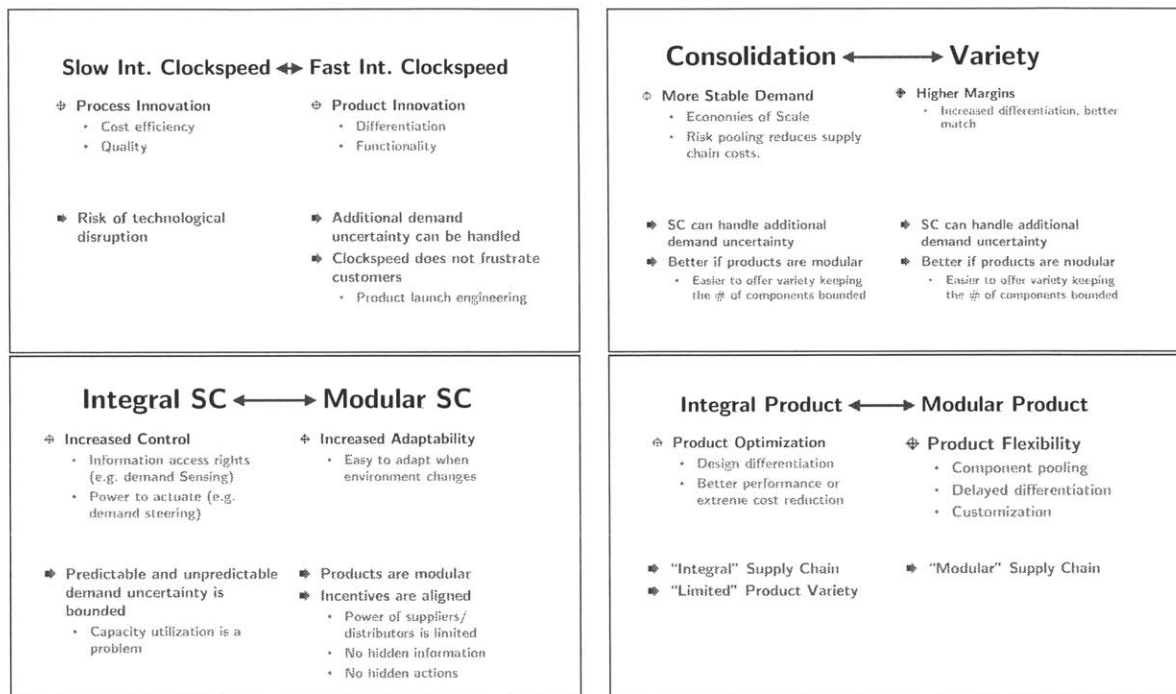
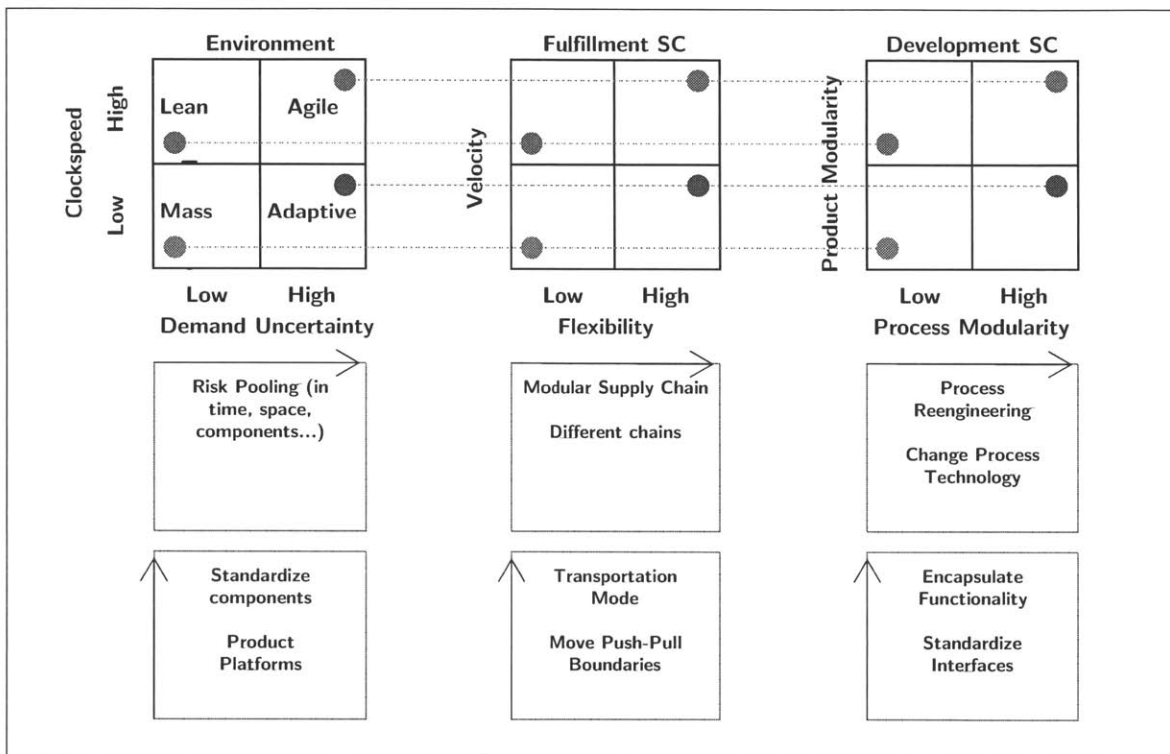


Figure 5-10: Impact of clockspeed, product variety, and product and supply chain modularity.





Note: boxes below list specific actions that can be used to align the dimensions in the horizontal and vertical axes.

Figure 5-11: Aligning fulfillment and development supply chain characteristics with supply chain strategic focus



# Chapter 6

## A Case Study on Zara

Zara is the main brand of INDITEX S.A., Europe's fastest growing apparel retailer.<sup>1</sup> INDITEX was introduced in chapter 2 as an example of a company that operates in a market with high demand uncertainty and fast product obsolescence, and whose entire business relies on the effectiveness of supply chain operations.

This chapter presents a case study in the apparel industry, taking Zara as a reference company, and presenting the design decisions in its supply chain in terms of the integrative framework presented in chapters 4 and 5. Zara's approach is compared to that of competitors H&M and Gap to illustrate the differences in the supply chains of companies competing in the same market, but with essentially different competitive strategies.

Case studies are among the weakest forms of scientific research, yet allow us "To see a world in a grain of sand . . . . And Eternity in an hour"<sup>2</sup>, provided that the example studied is rich enough. A specific type of examples that are specially valuable are those of companies that exhibit extreme characteristics compared to the average of the industry.<sup>3</sup> In terms of the key analysis factors identified in chapter 5, Zara is one of such extreme examples. It introduces four times more new items per year

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<sup>1</sup>Source: Alex Biesada, "Zara International, Inc.," Hoover's (<http://www.hoovers.com>, accessed 12 July 2005)

<sup>2</sup>William Blake's "To see a World..."

<sup>3</sup>This is in fact the approach that Fine (1998) follows, by studying companies that operate in fast Clockspeed environments.

than the average competitor, has concept-to-retailing cycles up to 12 times faster, and marks down less than half of the items compared to the industry average. Most importantly, Zara's supply chain is an extreme example of a pull-based architecture in an industry that has been traditionally dominated by push-based architectures.

## **6.1 Analysis Process**

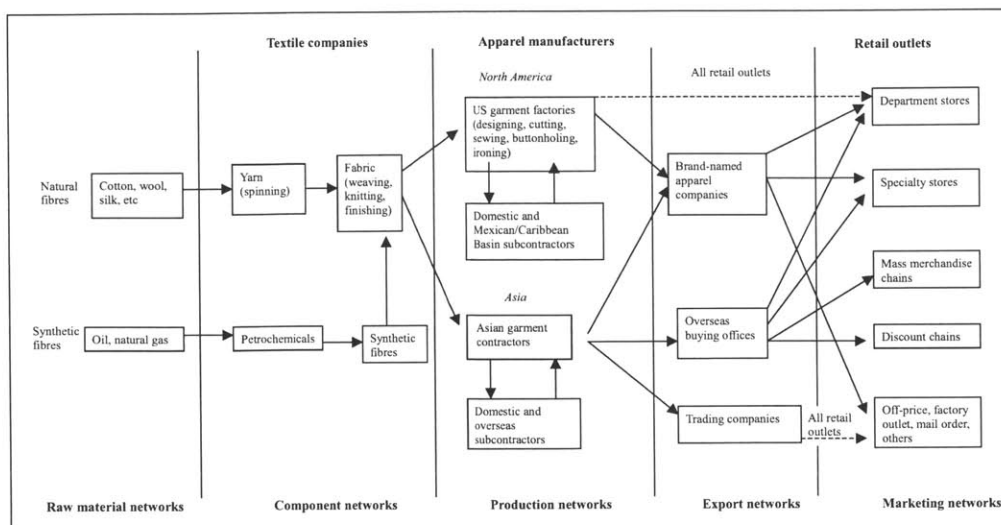
We will analyze Zara and INDITEX in terms of the analysis framework developed in section 4.2 on page 48:

1. Understand the characteristics of the industry and the market
  - (a) Regulation
  - (b) Industry Structure
  - (c) Capital Markets
  - (d) Technology Dynamics
  - (e) Business Dynamics
  - (f) Customer Preferences
2. Understand the strategy of the firm
3. Understand the internal constraints and capabilities of the firm
  - (a) Production System (upstream supply chain)
  - (b) Product Development
  - (c) Distribution System (downstream supply chain)

## **6.2 The Apparel Retailing Industry**

### **6.2.1 Industry Structure**

Textile and apparel production is a global industry that accounts for almost 10% of the world's manufactured exports. Heavily internationalized, it spreads across multiple



Source: Appelbaum and Gereffi (1994); Gereffi (1999)

Figure 6-1: Global Apparel Supply Chain

countries and has already experienced a number of international relocations (Gereffi, 1999). In the 1950's it migrated from North America and Western Europe to Japan. From Japan, it migrated to Hong Kong, Taiwan, and South Korea—the *Big Three* Asian apparel producers that dominated the exports in the 70's and the 80's. A third migration shifted production from the Big Three mainly to China after the opening of the Chinese economy in 1978, and also to a number developing regions including Sri Lanka, South-East Asia, some countries in South America, Turkey, North Africa and East Europe—the latter three mainly focused in exports to the European Union.

Apparel retailing supply chains are mediation-dominant: costs are concentrated in the downstream supply chain, and arise from demand uncertainty, inventory and distribution costs. While parts of the upstream production supply chain are scale-sensitive, such as fabric cutting or dyeing, others such as sewing and finishing continue being labor-intensive tasks performed by a fragmented network of providers (see Figure 6-1), many of them small workshops—47% of the cut and sew manufacturing establishments in the US had less than 20 employees in 2002 (US Census Bureau, 2004, pag. 2), and individual apparel manufacturing firms worldwide had an average of 12 employees in 2003 (Ghemawat and Nueno, 2003a).

In terms of upstream costs, raw materials usually account for about 50% of the

base production costs, and compensation accounts for an additional 25% (Abernathy et al., 1999, pag. 12). Labor can account up to 40% of the base production costs in developed regions such as western Europe (Nueno and Llano, 1999), so that manufactures tend to source production to low-wage countries, often distant from consumer markets. In general, apparel manufacturers own the brand, the design, sometimes the retailing stores, but very rarely they own the factories.

Sourcing to low-wage countries reduces labor costs, but introduces long lead times, that in turn force to plan collections up to nine months in advance to the season, leaving little room for reacting to changes once the season has started. The Gap Inc. has been facing this problem since the early nineties because of sourcing to the Far East, and even after large improvements in recent years, it is unlikely that lead times for Gap will drop below two months anytime soon. In contrast, H&M obtains better lead times by sourcing about half the production to Europe, closer to their main consumer markets, and Zara takes it to the extreme, manufacturing 70% its production in Europe, most of it very close to its headquarters.

## 6.2.2 Regulation

Since the 60's the textile and apparel industry has been subject of several regulation initiatives worldwide aiming at controlling the growth of imports. These initiatives culminated in the Multi-Fiber Arrangement (MFA) in 1974, which established a set of import quotas into a number of markets that include Western Europe, United States, and Canada.

While the MFA set specific mechanisms for updating annual quotas, but each country had its own way of distributing quota shares among exporters; as a result of convoluted trade agreements between countries, quotas may vary substantially by year, by country, and by item type. For example, The Gap Inc., who pays quotas in 70% of its products, would pay a quota visa cost of \$2 for a \$20 denim jacket from China, while a \$7 dress from India would cost only \$0.10.<sup>4</sup> INDITEX faced similar

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<sup>4</sup>Source: Nick Cullen, The Gap Inc. Chief Supply Chain Officer. Gap Inc. Investor Update Conference Call, Fair Disclosure Wire. 21 April 2005 (via Factiva).

problems in Mexico: apparel manufactured in Spain would pay 5% duty in virtue of a Mexico-EU trade agreement; in contrast, the same items would pay a 35% if manufactured in any part of Asia but China, and a 300% if manufactured in China.<sup>5</sup>

This complicated system of quotas introduces artificial constraints in a market that is international by nature, and distorts the logic design of the distribution system. For example, Mexican quotas might make attractive for INDITEX to source to China semi-finished garments, consolidate orders in Spain and apply a final process to the garments there, and then ship to Mexico—with arguably the same results for Mexico imports, but introducing inefficiencies that are ultimately paid by the end customer.<sup>6</sup> Standard & Poor’s estimated costs added by quotas and tariffs globally in \$330 billion in 2002, raising average prices a 34% (Standard and Poor, 2005).

The MFA was phased out in January 1, 2005, freeing global supply chains of these constraints and opening the road to large scale imports from the far East, mainly China, which accounted for 17% of the world’s apparel and textiles production in 2003, and was expected to increase to more than 50% in 2008.<sup>7</sup> For companies sourcing to the Far East, this means the opportunity to consolidate providers and achieve even greater efficiencies; however, for INDITEX it is expected to have a limited impact.<sup>8</sup>

### 6.2.3 Capital Markets

Two common demands of capital markets in the apparel industry are growth in the number of stores and increasing profitability. The first one places stress on the supply chain, as changes in the supply chain are much slower to implement than opening new stores, and the supply chain can lag behind the growth rate of the stores. Demand for increased profitability makes more appealing to increase sourcing overseas at the

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<sup>5</sup>See for example: “Inditex Under Investigation In Mexico.” Dow Jones International News, 27 August 2003 (via Factiva)

<sup>6</sup>INDITEX was in fact investigated in 2003 of suspected import irregularities, although it was cleared of charges one year later (see: Elizabeth Nash, “Fashion Giant Accused of Smuggling Scam,” *The Independent*, 28 August 2003 – via Factiva; and “Inditex cleared of Mexican import duty evasion,” *AFX European Focus*, 13 April 2004 – via Lexis Nexis)

<sup>7</sup>Source: WTO

<sup>8</sup>See for example: Leslie Crawford, “Zara races to retain speed of growth: Analysts worry that rapid expansion could come at the expense of the brand’s strongest asset,” *Financial Times*, 18 June 2005.

expense of flexibility and lead times.

However, having a controlling shareholder directly involved in the business—founder Amancio Ortega Gaona, INDITEX sees capital markets very differently than Gap and H&M. As CEO José María Castellano puts it:

“This company does what it believes it must do. . . . we are not limited by the capital markets. . . . We still have a controlling shareholder who, fortunately, continues to make the company’s strategic decisions.”<sup>9</sup>

INDITEX has indeed a *free float* (percentage of shares that are available to the investing public) of 40% as of June 2005,<sup>10</sup> while more common figures in the industry start at a 70% (H&M has a 70.7%<sup>11</sup>, Gap has a 75%<sup>12</sup>, Voegle has a 95%<sup>13</sup>). This gives INDITEX extra freedom in terms of choosing a competitive strategy.

## 6.2.4 Technology Dynamics

Upstream in the supply chain new weaving and knitting technologies and CAD/CAM combined with industrial cutting robots make now possible to manufacture individual clothing parts in hours with just a few employees (indeed, pattern cutting at Zara takes 4-5 persons and just a few minutes)—a process that not so long ago could take days, if not weeks. The same applies to packaging and loading for distribution in modern distribution centers.

In contrast, sewing rooms have evolved at much slower pace in comparison—essentially, the last truly breakthrough innovation in the sewing rooms was the introduction of the sewing machine by Singer in 1851. In addition, they are very intensive in labor, typically accounting for over 70% of the personnel (US Census Bureau, 2004).

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<sup>9</sup>José María Castellano, in Ghemawat and Nueno (2003a, Management Roundtable Video).

<sup>10</sup>Source: “Industria de Diseño Textil (INDITEX),” Credit Suisse Boston Ltd., 22 June 2005 (via Investex)

<sup>11</sup>Source: “Hennes & Mauritz,” Credit Suisse Boston Ltd., 23 June 2005 (via Investex)

<sup>12</sup>Source: “Gap,” CIBC World Markets, 7 July 2005 (via Investex)

<sup>13</sup>“Voegle,” Bank Sarasin & Co. Research Equities, 1 July 2004, [www.sarasin.ch/sarasin/pdf/EN\\_VCH040701.pdf](http://www.sarasin.ch/sarasin/pdf/EN_VCH040701.pdf) (accessed July 20, 2005)



The production system in use has been one of the main contributors to keeping sewing rooms isolated from technological innovation. The Progressive Bundle System (PBS), a push-based production technique introduced in 1930 was still used in 90% of the North American apparel industry in 1994 (Hill, 1994, pag. 30). In PBS, one sewing station would perform one action on a batch of items (a *bundle*) before passing the complete batch forward to the next station. Introducing changes in one step in PBS would unbalance the line, and therefore changes in the sewing rooms were postponed as much as possible (Abernathy et al., 1999, pag. 29).<sup>15</sup> In addition, PBS required intermediate buffers in each step, typically of one-day production in size, so that a piece of clothing such as a pair of pants, which requires about 40 different operations, can take up to 40 days to move from cut pieces to finished product (Abernathy et al., 1999, pag. 167).

Alternatives to PBS exist, but they have lacked widespread adoption. One of them is the so-called Unit Production System (UPS), a pull-based system that uses a batch size of one item. UPS has not been very popular because it requires significant investments in mechanical transports to move units of clothing from station to station, makes more difficult to balance the load of the line, and is less robust to downtimes and demand fluctuations: a failure in one of the steps would stop the whole line.<sup>16</sup> Another alternative is Modular Assembly, which consists in grouping sewing activities and assigning them to a team to reduce delays. Implementing modular assembly requires to change the layout of the workshops and the compensation schema in use; in general, it also demands more skilled personnel. In general, modular assembly is more expensive to implement and operate, and has lower steady-state throughput compared to PBS, but it is much more flexible and can easily achieve delay improvements of one order of magnitude.

Downstream, POS technology, bar codes, and modern telecommunications have

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<sup>14</sup>Further technological innovations upstream will have a negligible impact unless they improve sewing operations.

<sup>15</sup>This is actually a common problem to push-based systems—they are difficult to change by nature.

<sup>16</sup>These are all actually characteristics generalizable to all kinds of pull-based systems.

changed the way the industry operates by providing more data, faster, and more reliably, enabling new inventory management practices such as Vendor Managed Inventory (VMI) that blurring the traditional boundaries between retailing and manufacturing.

Demand characteristics are now easier to understand due to availability of data, and improved Information Systems to analyze it. This in turn has enabled better product portfolios and a more rationalized store base.<sup>17</sup>

Far from stalling, the trend is likely to continue with the introduction of RFID technologies in the apparel industry, that promise to provide even more data, of better quality, with greater frequency. Moreover, since the utility of this information is limited if it is not shared across the complete supply chain, and the required communications infrastructure to make it possible is already available, we can expect that visibility across the supply chain will increase—making boundaries between manufacturers and retailers even fuzzier.

### 6.2.5 Business Cycles

Consolidation of providers seeing greater efficiencies is the main foreseeable trend in the post-quota apparel manufacturing industry. Quoting Nick Cullen, Gap's Chief Supply Chain Officer:

In the past, quota required that we spread our sourcing across more than 700 vendors in 50 countries, and in some ways our size was actually a disadvantage. We were forced to diversify and fragment our spend, and we were limited into our ability to grow relationships with the best vendors. Our focus was diffused among 700 vendors. Now we're free to pursue strategic long-term partnerships.<sup>18</sup>

For companies like Gap, sourcing and purchasing were done at the brand level. Quotas limited the economies of scale that could be feasibly achieved, and it made no

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<sup>17</sup>In fact S&P attributes Gap's 7% same-store sales increase and 216% increase in profits in part to better IT and analytics (Wagle and Normand, 2005).

<sup>18</sup>Source: Gap Inc. Investor Update - Final. Fair Disclosure Wire, 21 April 2005 (via Factiva).

sense to consolidate sourcing across brands. In the post-quota era, sourcing can be pooled at the firm level, and economies of scale can be seek by consolidating providers and simplifying the sourcing network. As of April, 2005, The Gap Inc had dropped over 100 providers, and increased spending by 16% with the top 50 vendors.<sup>19</sup> For companies like Zara, the elimination of quotas will have a much smaller impact.

Consolidation is also expected among retailers, and as their bargaining power grows, they will attempt to place orders later in the season—making wholesalers and manufacturers bear inventory risks. Furthermore, manufacturers risk to be intermediated by large retailers such as Wal-Mart, who have scale to capture part of the efficiencies created by consolidation upstream. Analysts indeed expect private-labels to grow (Driscoll, 2005), putting stress on apparel retailers competing purely on the basis of cost. Competition is therefore expected to shift for these apparel manufacturers toward branding, innovation, and better shopping experience.

### 6.2.6 Customer Preferences

The apparel industry, especially fashion items, exhibit high demand uncertainty and volatility. Demand is *uncertain* because it is difficult to foresee well in advance the fashion trends for a certain season, and therefore the risk of 'fashion misses' is high — product failure rates can be as high as 10%. Demand is *volatile* because even having hit the right trend, demand may change suddenly due to a variety external factors—from weather, to social events: a \$25 Gap turtleneck stocked out the week after Sharon Stone wore it in the 1996 Oscar Award Ceremony.<sup>20</sup> In 2003, H&M attributed sales slowdown to a unusually cold winter followed of a very hot summer<sup>21</sup>—long lead times for goods from Asia left H&M no room for reaction; Zara was able to react, but two other INDITEX brands, Stradivarius and Pull&Bear missed the trend.<sup>22</sup>

Customer demand of “fresher” products has driven the industry to a competition

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<sup>19</sup>Ibid.

<sup>20</sup>Anne Kingston, “Bridging the Gap: The clothes are boring. The ads are fizzling. How did a retail giant wind up on the brink?,” National Post, 4 May 2004 (via Factiva)

<sup>21</sup>“Hennes & Mauritz - The Lex Column,” Financial Times, 16 August 2003

<sup>22</sup>RetailWeek, “Inditex special report - International player.” 21 November 2003 (via Factiva)

for shorter cycle times. In the past, two static collections per year were enough—spring/summer and fall/winter; nowadays, customers expect collections to be renewed more often. In 1998 the life span of a fashion trend was one year; by 2000 it was 5 months,<sup>23</sup> and nowadays it is measured in weeks.

Cycle acceleration doesn't affect equally to all kinds of products; some items are fast, while some others are slow moving by nature. Differences in speed are directly related to how fashionable the item is. Apparel is typically broken down in three categories according to its fashion content: fashion, fashion-basic products, and basic products (Abernathy et al., 1999, pag. 9). Fashion items such as designer dresses have short life times (at most one season), exhibit the highest design content, and sell small volumes per SKU. Basic items, such as socks or khakis have long life times (up to several seasons). Fashion-basic items usually basic items with some fashion content, exhibit characteristics in between Fashion and Basic products.<sup>24</sup>

## 6.3 Competitive Priorities

### 6.3.1 Competitive Priorities for Zara

Zara competes in cost and innovation – introducing fast many new fashion items at an affordable price, then adapting the collection to ongoing trends in the marketplace. Figure 6-2 shows how the company positions itself in the marketplace.

In section 2.3.3 we presented a number of practices of Zara that lead to think that cost and efficiency, while important, are not Zara's ultimate concerns. Quoting CEO José María Castellano:

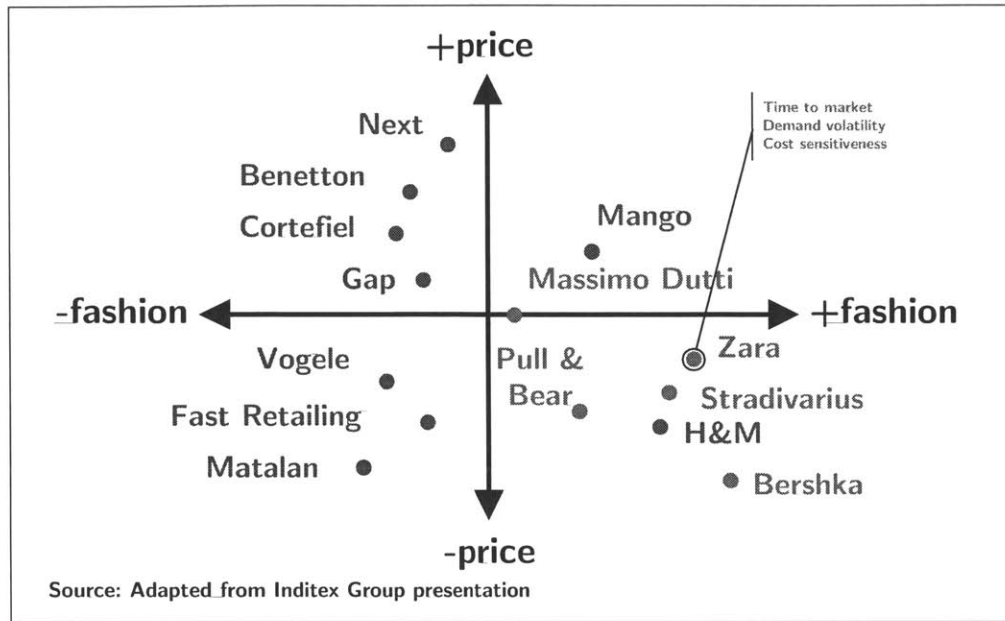
We have not got a price end of the market, and we don't want to be. And we don't need to be there at all – never. . . . we don't want to compete in pricing. . . . it would be a very big mistake.<sup>25</sup>

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<sup>23</sup>Anne D'Innocenzio, "Fashion's Fast Cycle," Women's Wear Daily 15 June 2000 (via Factiva)

<sup>24</sup>A direct analogy exists between the Fashion/Basic categorization and Fisher's 'Innovative/Functional' categorization: Fashion-basic items would correspond to represent functional products that have been differentiated through the addition of innovations.

<sup>25</sup>Q4 2002 INDITEX Earnings Conference call, 20 March 2003 (via Factiva)



Source: adapted from INDITEX Press Dossier 2003

Figure 6-2: Zara Positioning

In fact, as we will see in section 6.3.3 on the next page, these apparently inefficient practices actually support competition in innovation.

Finally, service occupies a second plane. Not only the company is known not to devote a great effort to achieving high service levels, but stockouts are sometimes intentionally created; demand is left unsatisfied in order to drive a “buy on the spot” mentality among shoppers (Nueno and Llano, 1999; Ghemawat and Nueno, 2003b; Ferdows et al., 2004).

### 6.3.2 Competitive Priorities for Gap and H&M

Table 6.1 compares the competitive priorities of Zara, H&M, and Gap. Both H&M and Zara offer products with high fashion content, but H&M attempts to balance fashion and costs, while Zara focuses in fashion. For Gap, cost is the major concern, and eclipses fashion. As Richard M. Lyons, Gap Division President put it in 2002:

‘they [Gap] have become so process-driven that it is not about product any more. It is more important where they get those one million units

made than what those units are.”<sup>26</sup>

Priority	Zara	H&M	Gap
A (optimize)	Innovation	Cost	Cost
B (bound)	Cost	Innovation	Service
C (best-effort)	Service	Service	Innovation

Table 6.1: Competitive Priorities of INDITEX (Zara), H&M and Gap Inc.

### 6.3.3 The right supply chain for your competitive priorities

Following the framework presented in Table 4.1, these three different competitive strategies demand supply chains with different performance characteristics.

Priority	Objective	SC Key Attributes
A (optimize)	Innovation	Flexibility, Sensitiveness, Resilience
B (bound)	Cost	Reliability, Responsiveness
C (leave free)	Service	Efficiency

Table 6.2: Zara – Competitive Priorities

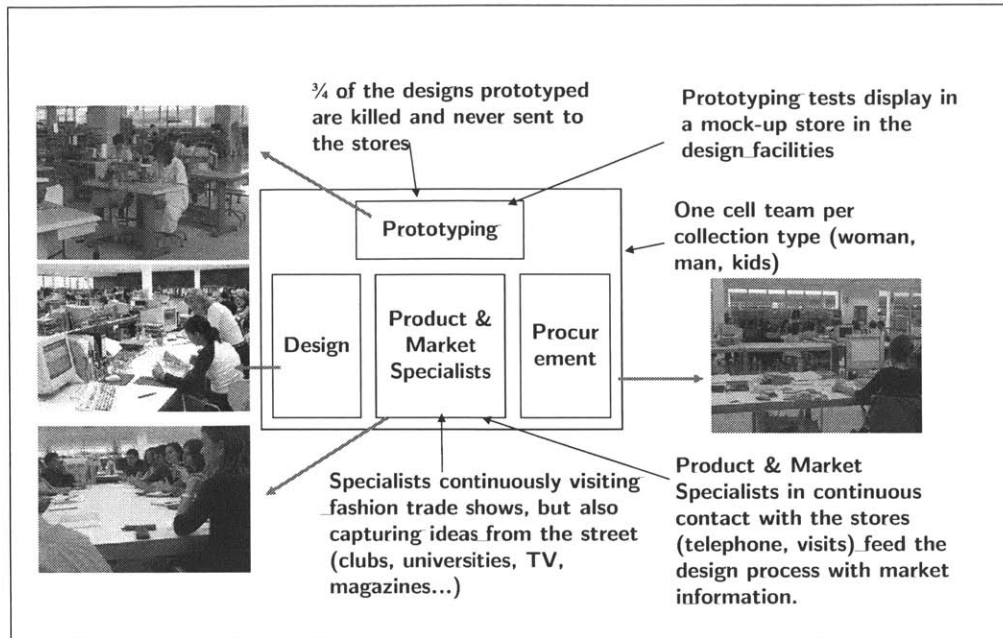
Zara will seek a flexible, sensitive supply chain that is also reasonably efficient. H&M will seek the exact opposite: an efficient supply chain that is reasonably flexible and responsive. Gap will focus on efficiency, as long as the seek for lower costs does not disrupt deliveries to stores.

## 6.4 Product Design and Development

Product design is centralized at the INDITEX headquarters in North-West Spain. Designs are done by multidisciplinary teams that include designers, product development, and sourcing specialists. Figure 6-3 depicts one “design cell.” There is one these cells per major section in a store—kids, men, women.

Product development specialists have access to sales data and past orders from retail stores, and stay in contact with store managers by phone or personal visits.

<sup>26</sup>Leslie Kaufman, “Scrambling To Regain Its Cool,” The New York Times, 24 February 2002 (via Factiva).



Photos by Xurxo Lobato/La Voz de Galicia and Ghemawat and Nueno (2003a)

Figure 6-3: Zara Product Design and Development Cell

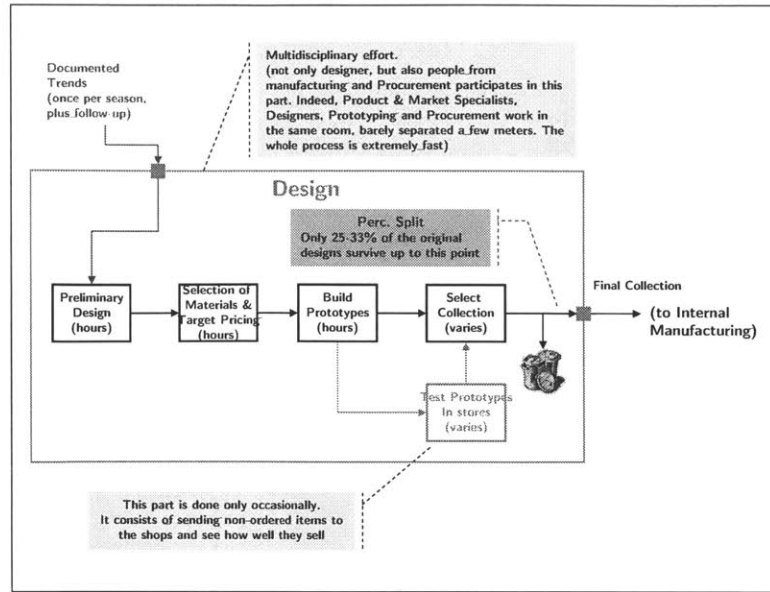
They bring feedback from the stores to the design table—what is selling, what the customers say, what could sell. This information is the basis of the decision of which items and how many items to manufacture.

Procurement specialists represent the voice of manufacturing, providing a reality check on cost and manufacturability of the designs. Not only this ensures that the items be manufactured on time, it also avoids mismatches between product and pricing early in the design process.

Designers travel around the world attending trade fairs and fashion shows. They also receive input from a task force of trend-spotters, who identify trends in a variety of sources—streets, TV, or magazines, to name a few.

Products are immediately prototyped by a small team of pattern cutters and sewers.<sup>27</sup> Samples can be produced as fast as in a few hours, and they are tested in a mock-up store in the headquarters. About 75% of the samples are discarded in an early stage. The surviving 25% can be sent out directly to manufacturing for mass

<sup>27</sup>This is actually only true for products that won't be sourced abroad; for these other products, designs are directly sent to sourcers, who send back a set of samples.



Source: compiled from published sources: (Ferdows et al., 2003, 2004; Fraiman et al., 2002; Ghemawat and Nueno, 2003a; McAfee et al., 2004)

Figure 6-4: Zara – Design Processes

production, or, if uncertainty is high, a small batch can be produced and sent to a few stores first to test market acceptance. Figure 6-4 presents a high level map of the process with an estimated time breakdown.

In general, stores “pull” orders from the main distribution center; however “risky,” all-new items may be directly “pushed” from the product development team to the stores in order to test the market. If the product performs well, additional batches can be produced as quickly as in just two weeks. If it doesn’t, it can be phased out and replaced by a new product in about three weeks. Figure 6-5 depicts the typical decision gates in a product launch.

Zara’s product design and development process encourages experimentation not only in the design room, but also in the marketplace. Zara’s low rate of product rejections compared to the industry average – 1% vs 10%<sup>28</sup> – can be largely attributed to it. By pushing the product introduction rate to its limits, and introducing 4-5 times more products than the average competitor, Zara is also accelerating learning about market trends and reducing risk. Zara does not offer more in-store variety

<sup>28</sup>Nueno and Llano (1999)



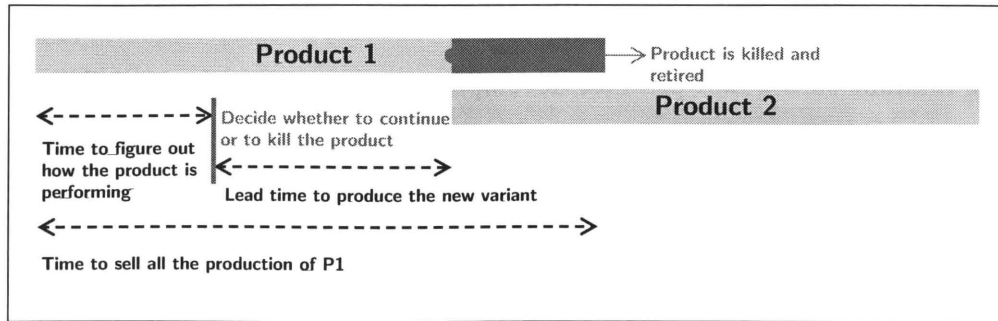


Figure 6-5: Fast product introduction in Zara

than its competitors, Zara just offers more variety *over time*. This fact, and the lack of concern for maintaining a high service level appears to contribute positively to steer the demand towards on-spot buying—because what’s in the store today, won’t be there next week: the average Zara customer visits the store 17 times per year, compared to the average 4 of the industry (Ghemawat and Nueno, 2003b). As Miguel Díaz Miranda, Vice-President of Manufacturing explains:

Sometimes we make a decision that from an economic point of view might not seem sound . . . we might have an item that was selling very well, but if we think that we are saturating the market with that look we will stop manufacturing it and create unsatisfied demand on purpose.<sup>29</sup>

### The right supply chain for your product development process

Zara’s product development process demands a very flexible production system and a fast and responsive supply chain. Flexibility is needed in the production system because it will be necessary to first produce small batches quickly and economically, then have the option ramp up the production fast, or phase it out completely depending on the success of the product. On the other side, the supply chain must be able to quickly deliver the items to the stores to start the market probing process, and since production will be carried in small batches, it will be necessary to deliver everything fast, replenish often, and signal early the response of the market. In short, this operation model demands a downstream supply chain that not only distributes

<sup>29</sup>As quoted by Fraiman et al. (2002)

goods effectively, but that is also able to sense market demand effectively, and feed back the manufacturing and product development processes with this information.

#### **6.4.1 Linking the supply chain and production system to the product development process**

Integrated teams link the product development process, the production system, and the supply chain, at the cost of requiring larger teams of designers with a unique profile—indeed, with 36,760 employees and about 300 designers in 2004, INDITEX has about twice as many designers per employee as H&M had.<sup>30</sup>

### **6.5 Production System**

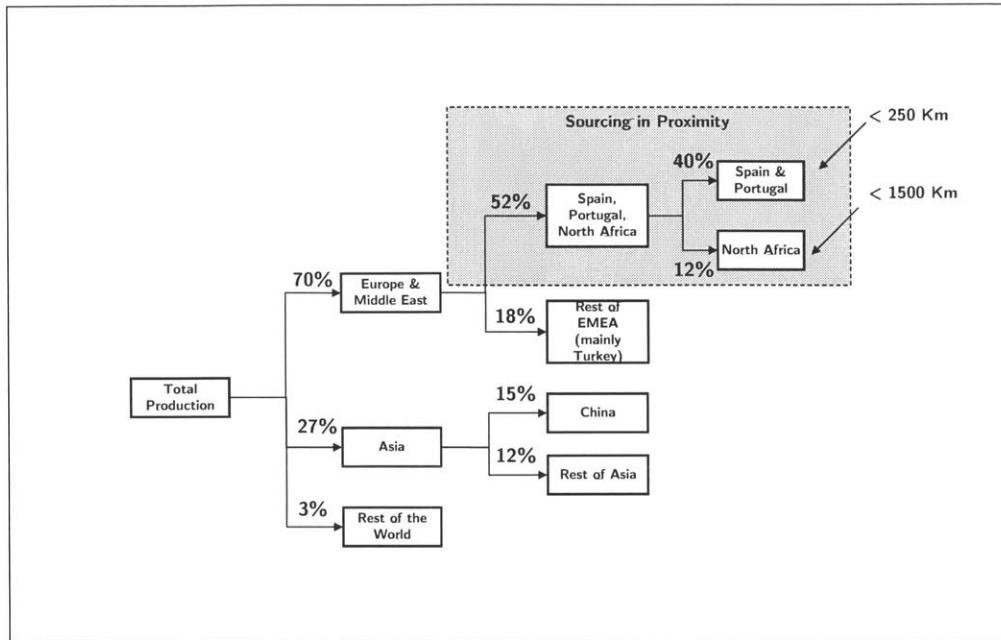
Zara’s sourcing and manufacturing has been designed to optimize production flexibility and fast demand sensing and reaction rather than costs. In order to achieve the short lead times that Zara’s product development process demands, more than 40% of the production is manufactured in Galicia (North-West of Spain), and in the North of Portugal (Figure 6-6), even though producing an item in Spain is 15-20% more expensive than producing it in Asia and then transporting it to Spain.<sup>31</sup> An additional 30% of the production (which used to be about a 40% in the past) is manufactured “in proximity” in Europe and North Africa, a tradeoff between low costs and longer lead times. As CEO José María Castellano explains it:

If I tried to source my collections in Asia, I would not be able to get them quickly enough to our stores. By manufacturing close to home, I can scrap collections when they are not selling. And without this rapid response, I

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<sup>30</sup>H&M had 31,700 employees and 90 designers in 2004 (Source: The Economist Intelligence Unit Ltd. (2005) and Sarah Raper Larenaudie, “Inside the H&M Fashion Machine,” Time, Spring 2004).

<sup>31</sup>As an example, Ghemawat and Nueno (2003b) provide a cost breakdown of a large men shirt in Spain and in Asia in 2001 from confidential industry sources. Total unit costs in Spain \$42.24, compared to \$29.09 when sourced in Asia, including transportation and rehandling costs, or about 45% savings.



Source: compiled from data in INDITEX FY2004 Results Presentation, 2003-2004 INDITEX Earnings Conference Calls (via Lexis Nexis), and Ghemawat and Nueno (2003b)

Figure 6-6: Zara Sourcing Breakdown

would not be able to extract a good relation between quality, price and fashion, which is what our customers have come to expect.<sup>32</sup>

Higher costs of local production are recovered through the premium customers are willing to pay for fresher, more fashionable items, and also via cost savings due to risk reduction – short lead times allow to introduce up to 40% of the apparel in-season, when demand uncertainty is lower. In contrast, competitors such as Gap must prepared collections 6-9 months in advance, due to lead times introduced by sourcing to the Far East, and can't be easily changed in-season. H&M adopts a compromise: sourcing close to half of the production to Europe, H&M can reach good economies of scale, while keeping lead times short – about 50% longer than those of Zara, but still very good by industry standards.<sup>33</sup>

<sup>32</sup>As quoted in Leslie Crawford, "Inditex sizes up Europe in expansion drive: Rapid design, manufacture and distribution keep pressure on rivals," Financial Times, 1 February 2005 (via LexisNexis)

<sup>33</sup>Sarah Raper Larenaudie, "Inside the H&M Fashion Machine," Time, Spring 2004.

Table 6.3 presents a comparison of the sourcing policies of Zara, H&M, and Gap as of June 2005.<sup>34</sup>

Region	IDTX	H&M	Gap
EMEA	70%	40%	
China	15%	30%	
Other Asia	12%	30%	70%

Source: Castelló and Castellano (2005); H&M (2005); Inc. (2005)

Table 6.3: INDITEX, H&M, and Gap sourcing breakdown (as of June 2005)

Gap compensates limitations of its Fulfillment Supply Chain in the Product Development Process, by designing less fashionable items that have a coherent style throughout the season, as opposed to even attempt to following trends as Zara does. As Gap's Louise Trotter, VP of Women's Wear puts it:

. . . if fashion is less important in your life, Gap can give you a certain style, from head to toe. . . . our eye is not on fast fashion or copying trends for the masses, our eye is on giving style to the masses.<sup>35</sup>

So in essence, Gap relies on a push-based system that requires planning collections well in advance and avoiding changes once the season has started, and matches it with an also push-based product development process, where a collection is designed with a consistent style that does not aim at following trends.

Far from even attempting to achieve high utilization ratios, factories in Spain devoted to the capital-intensive operations of knitting, dyeing, and cutting are run on a single shift, and distribution centers are run well below their maximum utilization rates (Ferdows et al., 2004). In fact, the second distribution center (Zaragoza) was deployed in a moment when the first one was being used below 50% capacity. Ferdows et al. (2004) suggest that Zara overdimensions capacity in order to minimize delays (from the standpoint of queueing theory, delays usually increase non linearly with the utilization factor).

<sup>34</sup>In 2004 H&M sourced 40% of the production to Europe, about 30% to China, and the remaining 30% to other regions in the Far east (H&M, 2005).

<sup>35</sup>Cat Callender, "How Gap got its groove back," The Independent, 8 November 2004 (via Factiva)

Manufacturing is designed for flexibility and small batches. Factories were designed with the help of Toyota, and follow Toyota Production System principles—one operator controls several machines, typically between one and three (Nueno and Llano, 1999; Álvarez, 2001). In this way, changes in the production can be executed quickly and without need to rebalance the lines. It is therefore a highly modular production system. As Miguel Díaz Miranda, Vice-President of Manufacturing explains:

The size of the production run – scale, in the traditional sense – is not an issue. We recoup our costs on the garments through markup because people will pay a premium for the right garment at the right time.<sup>36</sup>

Manufacturing processes are highly automated – cutting, for example, is executed by robots directly from CAD models with minimal human intervention. However, there is no automated schedule planning and optimization: factory managers are simply presented quantities and due dates and they decide the schedule (McAfee et al., 2004). This apparent lack of sophistication is an invariant in Zara’s information systems, where human supervision is favored over complete automation. A common complain of any manufacturing planning system—and this includes MRP, MRP2, or ERP modules for management of production—is that the systems are often too rigid to accept changes once a production has been laid out. A more “organic” approach such as that of Zara is probably less efficient for mass manufacturing with stable, long run production schedules, but allows for a much greater flexibility and permits rescheduling the initial plan as needed.

Sewing is contracted to local workshops, most of them located very close to Zara’s main premises in Galicia and the North of Portugal. These workshops are one of the enablers of Zara’s responsiveness to demand changes. As CEO José María Castellano explains:

The proximity of our suppliers, especially those who make clothing with greater fashion content, is essential if we are to maintain a flexible response to the changing trends that can occur within each collection.<sup>37</sup>

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<sup>36</sup>As quoted by Fraiman et al. (2002)

<sup>37</sup>As quoted in Castelló and Castellano (2005)

Most of the workshops maintain long-term relations with Zara, which is their main customer, and also their main provider of equipment. Workshops are the ultimate enablers of Zara’s flexibility to introduce products in-season: they are scale-insensitive and able to produce small batches economically. Most importantly, they are flexible, accepting capacity reservations from Zara without requiring garment specifications to be provided in advance. This allows Zara to keep the designs open up to the last moment, in a way that closely resembles Toyota’s Set Based Design.

Overall, modular manufacturing performing the capital-intensive operations of dyeing and cutting, combined with flexible workshops performing the labor-intensive operations of sewing and assembling, allows Zara to produce in small batches economically and ramp up the production fast as needed, or phase-out underperforming products quickly and with minimal costs. In this way, the production process aligns and supports the product and the product development process.

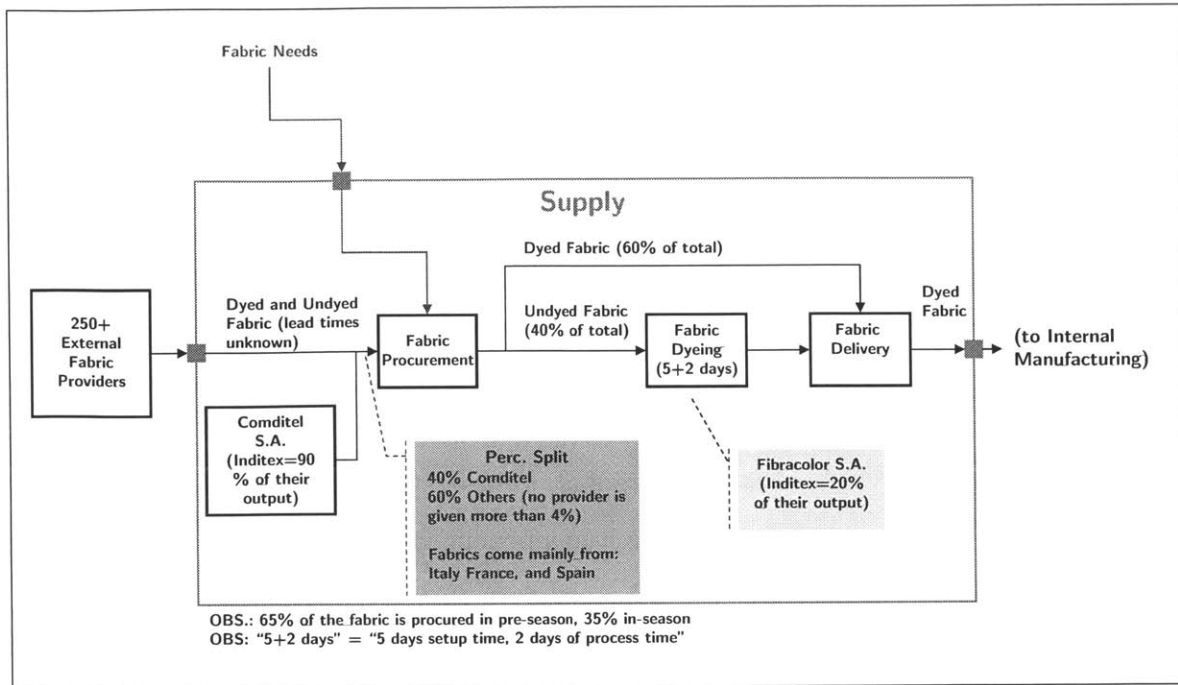
## **6.6 Supply Chain**

Zara’s supply chain design reflects the competitive priorities identified in section 6.3 on page 88: the distribution network has clearly not been designed not with costs in mind, but to support fast and frequent introduction of products.

### **6.6.1 Upstream Supply Chain**

Fashion items, representing about half the total production are insourced and manufactured in the production system described in section 6.5, which allows Zara to introduce more products in-season, when demand uncertainty is lower. Table 6.4 presents a breakdown of Zara’s production commitment for these items versus the industry average.

Undyed fabric is bought in large quantities from a network of more than 250 external providers, most of them in Europe, plus from an owned fabric procurement company – Comditel S.A., for which INDITEX represents 90% of the output. External providers account for 60% of the fabric procured, but no external provider is



Source: Fraiman et al. (2002)

Figure 6-7: Supply management and procurement processes at Zara

	Pre-season	Start of Season	In-Season
Zara	15-25%	50-60%	40-50%
Industry	45-60%	80-100%	0-20%

Source: INDITEX Group Presentation, 2003

Table 6.4: Apparel Production Commitment – Zara and traditional industry model average

given more than a 4% of it. This mixed procurement strategy keeps Comditel S.A. competitive, while secures a large fraction of the supply, hedging against potential supply problems. Pieces of apparel sent to external workshops for sewing return to the same factory that cut the fabric transformed into assembled apparel. There they are quality-inspected control, finished, and tagged. Finished clothes are packaged and sent to distribution centers for delivery to stores.

Basic items are planned during the pre-season and sourced abroad.<sup>38</sup> This sourcing policy adds a lead time of 2 months to items sourced to Turkey and Eastern Europe, and of 4 months to items sourced to Asia. This is not a problem for basic items, since

<sup>38</sup>These products, such as socks or khakis, qualify as *functional* products in Fisher's framework

volumes are predictable and also items have longer lifetimes.

Basic items are consolidated at the main distribution centers in Spain, where their distribution interleaves with that of fashion products (see Figure 6-9). Only cosmetics and footwear are sent directly from the manufacturing points to the stores (Blanco and Salgado, 2004), the latter from its own distribution center in Valencia (East Spain).

The upstream supply chain therefore overlays essentially two flows of goods:

- A flow of basic items that uses a global, *push-based* supply chain – slow, inflexible, but very cost effective. Basic items benefit from the efficiency that do not erode margins; since they don't obsolete fast, they are insensitive to lead times; since they are predictable, they can be safely stocked and replenished according to a plan.
- A flow of fashion items that uses a local *pull-based* supply chain – fast, and flexible to delay design decisions until demand uncertainty has been revealed, and to adapt to changes in the demand patterns.

### 6.6.2 Downstream Supply Chain

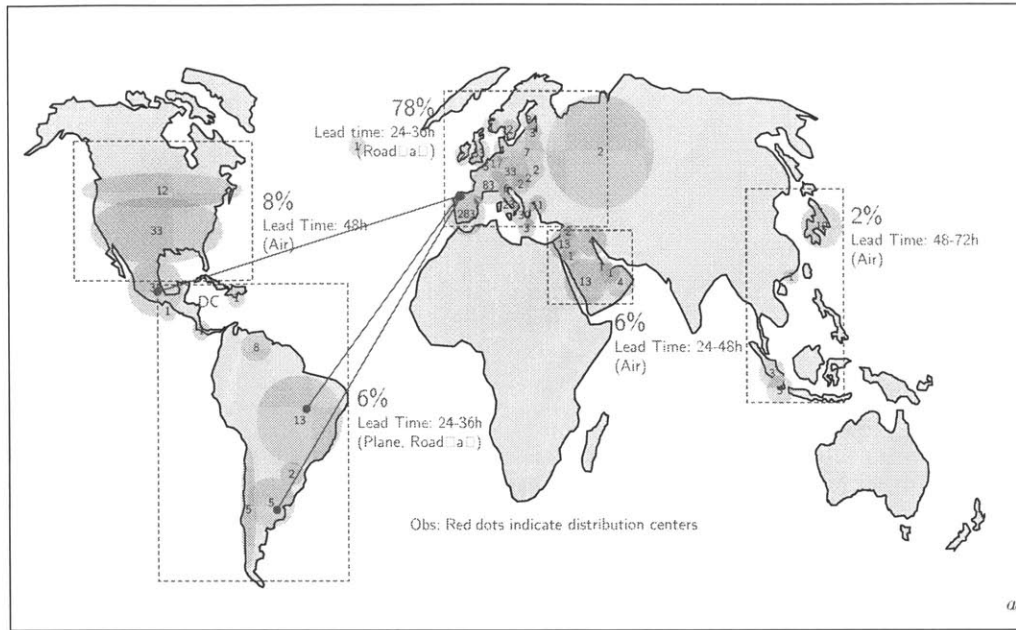
The distribution network (see Figure 6-8) is centralized in two distribution centers (DC's) in Spain: A Coruña, with capacity to relay 45,000 garments per hour, serving the Iberian, American and Asian markers, and Zaragoza, with capacity for 80,000, serving the European market.<sup>39</sup> Smaller regional distribution centers exist only in three locations in South America. There are actually no warehouses—goods are either in transit or in the shelves of the retail stores (stores have limited backrooms, or even no backrooms at all). The absence of intermediate storage decreases both inventory risks and inertia in the distribution pipeline.<sup>40</sup>

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<sup>39</sup>Source: Ghemawat and Nueno (2003a) and INDITEX Press Releases – available at [http://www.inditex.com/en/press/press\\_releases](http://www.inditex.com/en/press/press_releases)

<sup>40</sup>When a distribution channel carries abundant inventory, new products can't be introduced as fast as possible because that would obsolete the whole inventory already in the distribution pipeline—hence the name of “inertia.”





<sup>a</sup>Source: compiled from published sources (INDITEX, 2005; Ferdows et al., 2003) and the Zara Store Addressbook (accessed March 22, 2005 at: <http://www.zara.es>)

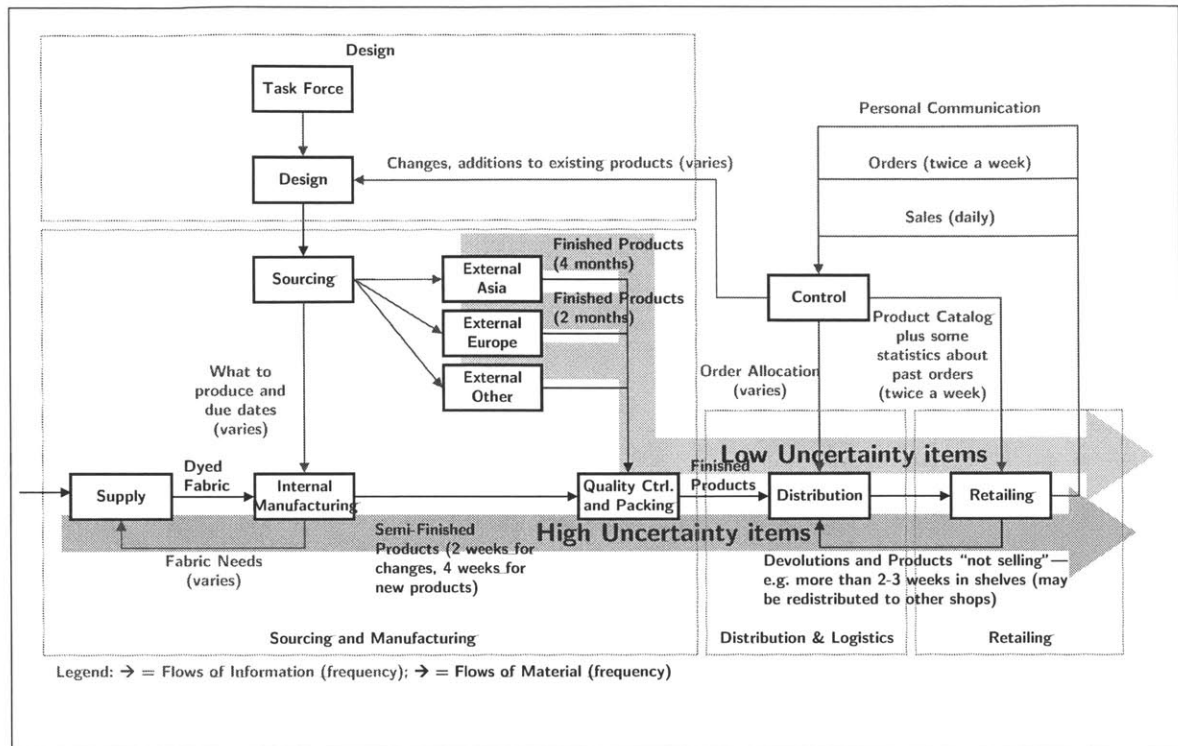
Figure 6-8: Zara Supply Chain Network

Distribution to the European market is carried by truck; the rest of the world is replenished by air cargo, even if that implies additional costs on the product.<sup>41</sup> Deliveries do not hold orders until an economic order quantity is achieved; instead, they follow strict periodic delivery schedules—twice per week for most of the brands, even if that implies “sending a half-empty truck across Europe” (Ferdows et al., 2004). The result is a network with almost constant lead times, no matter in what part of the world the demand sink is, and almost zero variance in deliveries, which are essentially free of deviation.<sup>42</sup> Figure 6-9 presents a general view of Zara’s supply chain, and Figure 6-7 zooms into the supply procurement process of the general view.

In terms of supply chain integration, Zara is vertically integrated both upstream and downstream, controlling fabric procurement, sourcing and manufacturing, logistics and distribution, and retailing. This contrasts with competitors such as Gap and

<sup>41</sup>More than 10,000 metric tons are sent by air per year (Blanco and Salgado, 2004); according to Jose Ruiz, Deputy Head of research at Kepler Equities, this practice yields up to a 20% increase in price in certain regions compared to H&M (Wahlgren, 2005).

<sup>42</sup>Overall, this gives the network a great predictability, and is one of the reasons why INDITEX can manage its operation with a very limited investment in Information Systems for logistics planning.



Source: compiled from data disclosed in published sources – Ferdows et al. (2003); Fraiman et al. (2002); Ghemawat and Nueno (2003a); McAfee et al. (2004)

Figure 6-9: General view of Zara's Supply Chain

H&M, that are vertically integrated downstream, but outsource all their manufacturing operations.

Formal pre-season forecast and planning exists only for basic items—no forecast at all is used for fashion items. Instead, stores are polled for an initial short-term estimation of how many units certain items can sell which is used to produce the first batches; production is ramped-up as needed afterwards.

In a similar way, replenishment is completely demand-driven, instead of being managed according to a central forecast, store managers make their own demand estimations, decide what and how much to order, and place two orders per week per each of the sections of the store—kids, men, women (Ghemawat and Nueno, 2003a; McAfee, 2004). Sales incentives keep store managers aligned with the best interests of the company. These orders are placed not to an intermediate warehouse, but to a central distribution point close to the factories, so that order information feeds

directly into the manufacturing process.

Store managers download electronically the current product catalog twice per week and place an order 24 hours after. Ordering deadlines are stringent—if one store fails to meet them, the distribution center will by default repeat their last order (McAfee et al., 2004). This deadline-orientation is required to synchronize the stores with the delivery schedule (Ferdows et al., 2004).

Overall, we can say that Zara’s supply chain is split in two parts—upstream, and downstream. The downstream part is common to all products, and it completely demand-driven, following a pure pull strategy. In the part upstream, fashion items (those with high demand uncertainty) flow following a pure pull strategy, while basics (very predictable demand) follow a push strategy. So we have a push/pull chain for basic items, and pull/pull chain for fashion item. The common pull part is enabled via a modular design of the chain, that decouples production from distribution.

### **6.6.3 Information Management**

Stores report daily sales and bi-weekly orders through a PDA based application that interfaces with the POS. The system was developed internally, as most of the information systems infrastructure—from POS to the accounting system. The only systems that have not been developed internally are those that were purchased as part of a complete solution, such as pattern cutting software or distribution center conveyor control software, and even in those cases, all the interfacing with these systems was done internally.

Even though IT is fully insourced, Zara’s IT spending as a percentage of revenue is about five times smaller compared to the average apparel retailer in the US (McAfee, 2004). Finally, marketing, design, procurement and manufacturing are tightly integrated in the design process.

Systems are relatively simple compared to market standards—POS systems are built on a now obsolete version of MS-DOS, and the whole ordering process relies entirely on an IBM AS/400 server. As presented in section 6.5, manufacturing planning systems and data analytics software are almost completely missing from the pic-

ture. Batch scheduling is done by humans, and even the pattern cutting process goes through a human-made optimization after a computer has done a pre-optimization. In a similar way, stores receive reminder information about the historic of past orders and other simple information that may be helpful in the ordering process – but they have the last word. Xan Salgado Badás, Director of Systems is skeptic that advanced analytics or forecast technologies based on data mining of POS data can actually outperform the personal criteria and experience of product and store managers; even though some software has been developed to aid them in taking replenishment decisions, it still behaves more as a desktop calculator that aids—not replaces human decision making.<sup>43</sup>

The way information is managed deserves an special mention. Inventory is loosely tracked, aiming to a 95% accuracy, but not more. Inventory is tracked at Zara’s headquarters as the difference between sales and orders placed by the stores—what is called “theoretical inventory” (McAfee et al., 2004). Shrinkage is controlled through periodic audits, which group items not even at the SKU level, but at the *tag price* level, which yields enough precision and is simpler to implement.<sup>44</sup> If the store has less than a 5% shrinkage, the inventory is written off and the theoretical inventory corrected in the system. According to CIO Xan Salgado, the value of a 5% additional accuracy does not justify the cost of the implementation.

Inventory information is actually not very used in the decision-making process – as of July 2004, POS’s systems can’t query in-store theoretic inventory, so that a visual inspection must be carried every time an order is made, or even every time a customer asks for a certain product. The only decision point where the theoretical inventory is used is to prioritize replenishments when orders received at the headquarters exceed available production capacity.

Aside the periodic exchange of information of sales and orders, stores are permanently in contact with market specialists who work in the design process. Market specialists get from the stores the voice of the customer and suggest changes in ex-

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<sup>43</sup>Source: interview, Arteixo, 29 December 2004

<sup>44</sup>Source: interview with Xan Salgado Badás, Arteixo 29 December 2004

isting products (such as colors or fabrics), as well as new products. In this way, two channels overlay—a structured, fully automated one which used for “low resolution” information (sales and orders sent on a regular basis) and a non-structured one which is used for ‘high resolution’ information (feedback from personnel at the stores).

Reliance in informal communication and store decision-making places stringent requirements in the hiring process. Finding local personnel that can work in such environment is often cited as one of the major attributed difficulties for global expansion, and has indeed been a source of problems in countries such as France, where a certain degree of formalism was expected (Bonache and no, 1997).

Zara’s “organic” approach to IT contrasts with Gap. Ken Harris, CIO of Gap 1999-2003 favored buying software instead of developing it internally,<sup>45</sup> and indeed as of today Gap uses a wide variety of software packages: planning, forecasting, supply chain, warehouse management and inventory management from Retek;<sup>46</sup> Financials and Purchasing, iProcurement and Product Development Exchange from Oracle,<sup>47</sup> revenue management (mainly optimum markdown prices and schedules) from Profit-Logic, POS and store optimization from 360Commerce,<sup>48</sup> or transportation management from i2<sup>49</sup> to name a few.

These differences in the patterns of IT investment of both companies seem to be essential rather than accidental:

1. Zara operates in a more uncertain environment, and deals with this uncertainty by accelerating operations and favoring responsive action over accurate planning

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<sup>45</sup>“Summit Focuses on Point IT and Operations Merge,” Chain Store Age, 1 July 2005. Gap is known to have run their supply chain using internally developed mainframe software at least until late 2001 (see: Al Seania, “A New Fit for The Gap,” VARBUSINESS 3 September 2001 – via Factiva).

<sup>46</sup>“Gap Inc. Selects Retek Planning Solutions to Transform Supply Chain,” PR Newswire, 21 May 2001; and Al Seania, “A New Fit for The Gap – Eyeing the future, the retail giant is spending big on IT initiatives, despite the economic slowdown,” VARBUSINESS, 3 September 2001 (via Factiva)

<sup>47</sup>Ibid. (Valerie Seckler, “Gap in Deal with Oracle for e-Business Software,” Women’s Wear Daily, 23 July 2001)

<sup>48</sup>“360Commerce Announces that Gap Inc. has Chosen Their Suite of Store Optimization Software,” Business Wire 1 July 2002 (via Factiva). CIO Ken Harris provides a description of how The Gap Inc. uses 360Commerce in “Bottom Line Per... Gap CIO Ken Harris,” Baseline Magazine, 13 January 2004 (<http://www.baselinemag.com/article2/0,1397,1435130,00.asp>)

<sup>49</sup>“Gap Inc. Selects i2 for Global Transportation Management Initiative,” Business Wire, 17 September 2002 (via Factiva)

and forecasting; essentially, what Zara is doing is *sampling* faster the demand, and reacting accordingly. This is the reason why very simple planning systems are enough for Zara – it is not necessary a great sophistication to make a demand estimation when the forecasting period is as short as half a week. On the other hand, execution of operations in this way requires extreme flexibility, and this is the point where insourced IT becomes an opportunity. In fact, Xan Salgado Badás, Zara’s Director of IT, and also former CEO José María Castellano’s argument in favor of insourcing is that Zara’s operations are so unique that no commercial package can actually fit the model.<sup>50</sup> In addition, since the whole supply chain operates at a faster pace and relies in its responsiveness to correct errors, it is also more tolerant not only to demand uncertainty, but also to information of lower quality in general—as happens with inventory tracking.

2. Gap operates in a more stable environment compared to Zara, at a slower clockspeed, and seeking efficient production. In this situation—producing less fashionable items that are more stable and easier to predict and facing long cycle times that accept planning—decision support systems are essential. Operation support systems are still important, but since clockspeed is slower, there is less strain on them. Lack of responsiveness leaves no room for reaction, and forecast errors are paid with inventory and markdowns.

## 6.7 What we learn from Zara

The analysis presented reveals a number of interesting characteristics of Zara’s supply chain:

1. Zara operates a pull-based supply chain for fashion items, where demand is not only driving replenishments, not even driving production, but driving the design process: in the context of the L-model, it is hooked directly into the product development supply chain. Basic items use a push-pull supply chain: they are

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<sup>50</sup>Source: interview with Xan Salgado Badás, Arteixo 29 December 2004

planned in advance and sourced abroad using a push-based supply chain, and then distributed and replenished the same pull-based supply chain that fashion products use downstream.

2. In the foundations of this pure pull system we find a very flexible production system, and a low latency, very reliable supply chain. Flexibility in the production system comes from local manufacturing operations loosely based on the principles of the Toyota Production System, and most importantly, close partnership with local providers. Supply chain reliability comes at the cost of a very simple distribution network that operates in a synchronous mode, with almost constant delivery lead times anyplace in the planet – time, rather than base product cost has been kept constant.
3. Demand uncertainty is reduced by extensive prototyping in early stages, and later on via a pre-mass production stage, where small batches of apparel are put in the stores to test the market. By accelerating product introduction, Zara is also speeding up the learning cycle and reducing risk, but in order to achieve it, the product development process demands flexibility to the production system, and speed and responsiveness to the supply chain.
4. Integrated development teams make the system to stick together. Product design, production (sourcing and manufacturing) and distribution are engineered in the same team – thus minimizing the risk of mismatches.
5. While both production system and supply chain may appear inefficient and overdimensioned by traditional standards, a more careful inspection reveals that this inefficiency is actually enabling options that are essential for supporting company operations – they enable shorter lead times, smaller production batches, and lower inventories.
6. The information architecture follows the supply chain architecture. Investment is concentrated in Operations Support Systems, and IT insourcing provides additional flexibility.





# Chapter 7

## General Motors

The auto distribution channel is a kind of hourglass with the dealer at the neck. At the top of the class, plants, which introduce innovations in color and technology every year, can provide an almost infinite variety of options. At the bottom, a multitude of customers with diverse tastes could benefit from that variety but are unable to because of dealers' practices at the neck of the glass. – Marshall L. Fisher<sup>1</sup>

In May 2005 Standard & Poor's downgraded to the "below investment" category the bond ratings of the two largest US car manufacturers, General Motors Corporation and Ford Motor Company. Both companies had seen sales decline 4.6% during the first three months of 2005, even though demand went up 1.2% during that period. Ford's profits dropped 38% down to \$1.2 billion, and General Motors 80% to a \$1.1 billion loss.<sup>2</sup> Overall, the automobile manufacturing sector was one of the worst performing in the S&P 500.

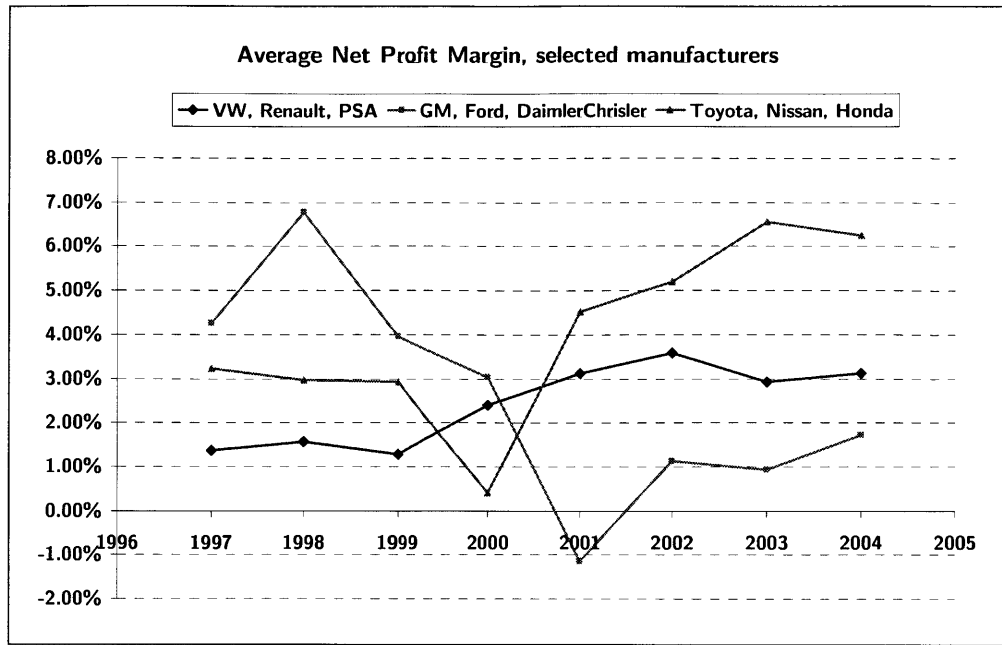
In contrast Japanese manufacturers did well – Nissan experienced record profits of \$4.8 billion, Honda made some \$4.5 billion, and Toyota, even after unfavorable currency fluctuations, managed to make \$5 billion. Only one Japanese company – Mitsubishi – had losses.<sup>3</sup> Figure 7-1 presents the evolution of the margins of the

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<sup>1</sup>Quoted from Fisher (1997).

<sup>2</sup>Source: Levi and Ferazani (2005)

<sup>3</sup>Source: Levi and Ferazani (2005)



Source of data: Hoovers. Figure shows sum of net income divided by sum of revenues. If Fiat had been included, European margins in 2004 would be similar to those of the Big Three.

Figure 7-1: Average margins for volume automotive manufacturers in Europe, Japan, and the US

Big Three compared to the three main Japanese manufacturers, and the three main European volume manufacturers.

The problems GM and Ford are experiencing are often attributed to soaring costs of future obligations such as pensions and healthcare expenses of retired workers. However, while these costs are a major problem, a deeper analysis shows that the challenges these two companies are facing are much more complex, and greatly related to the way their supply chains have been designed.

This chapter presents an analysis of the challenges GM's supply chain was facing in 2005, and proposes two specific corrective actions.

## 7.1 The US Automotive Industry

### 7.1.1 Industry Structure

The US is the largest automotive market of the world, estimated in some \$400 billion in 2004, and expected grow a 1.7% CAGR until 2008.<sup>4</sup> The “Big Three” (General Motors Corp., Ford Motor Company, and Daimler/Chrysler) have been steadily losing market to foreign producers since 1978, from a 84% then down to a 63% in 2003 (Roos, 2004). However, they still are the major producers in the US.

#### **Upstream: Tiered Providers and Capital Intensity**

Upstream, the industry is capital intensive, with large plant fixed costs—a new plant typically costs over \$1 billion. The industry has evolved into a complex network of providers organized in tiers from a structure of vertically integrated manufacturers. The decade 1995-2005 has been characterized by manufacturers outsourcing more of their processes to Tier-1 providers such as Delphi, Visteon, or ArvinMeritor. These providers now deliver systems (also called “modules”) ready for assembly directly to the factories. Tier 2 providers focus on sub-subsystems, tier 3 on components, and the rest of tiers on basic components and raw materials.

Economies of scale and efficient factory capacity utilization have traditionally been major concerns in the industry, and as such, object of continuous improvement. However, as we will see in section 7.4, improvements in have been largely achieved at the cost of manufacturing flexibility, and the seek of scale has created excess manufacturing capacity.

#### **Downstream: Dealerships, Incentives, and Inventory**

The downstream supply chain is based on a vast network of independent and chains of dealerships, some of them publicly traded. Dealers, not automakers, own the relationship with the customer, a valuable asset, since parts and post-sale service

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<sup>4</sup>Source: Datamonitor “Automobile Manufacturers in the United States - Industry Profile,” October 2004, ref. 0072-2010 (via Business Source Premier)

account for 47% of profits—even though they represent only 12% of the dealer’s revenues.<sup>5</sup>

Despite the difficulties automakers, dealers are still very profitable. Automakers bear most of the cost of the sales, and arguably a good part of inventory risk.

As for the cost of sales, in 2002 AutoNation was spending in marketing an average of \$300 per car, compared to the \$500 spent by the automaker.<sup>6</sup>

In terms of inventory risk, automakers finance a certain amount of inventory in stock in the dealerships. In general, the target inventory level at the dealerships is 60 days for the whole industry; however, dealers typically get payment allowances longer than that—90 days in the case of GM. In May 2005 the average industry inventory turnover was 76 days,<sup>7</sup> a significant improvement from the 83 days registered in November 2004, but still off target. As we will see, these inventory levels are mainly a direct consequence of the *push* logic embedded in most automaker’s operations in the US; however, the effect of misalignment of dealer’s incentives can’t be dismissed: GM dealers do not have incentives to optimize the car portfolios in their parking lots to turn fast, but to yield the maximum profit, provided that interests must be paid after 90 days.

In addition, automakers issue nationwide customer discounts and other incentives to push slow-moving cars out of the dealerships by the end of the season. Average incentives per car sold in the US were estimated in \$1,873 in 2002 Miemczyk and Holweg (2004), and for GM they have been growing since then above industry average rates, up to \$4,141 per car in the first quarter of 2004.<sup>8</sup>

## 7.1.2 Regulation

As of July 2004, the automotive industry in the US faces problems related to regulation both upstream and downstream in the supply chain—problems that are unlikely

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<sup>5</sup>Source: National Automobile Dealers Association, as cited in Plunkett’s Automobile Industry Almanac 2003 (via ).

<sup>6</sup>Source: Plunkett’s Automobile Industry Almanac 2003, ISBN: 1-891775-76-6.

<sup>7</sup>Source: Standard & Poor’s (see Levi and Ferazani (2005)); Ford and GM are above average.

<sup>8</sup>Source: J. P. Morgan Chase. GM spent \$3,253 in the same period in 2003.

to be solved in the short term.

### **Upstream: Inflexibility**

The Big Three are unionized and have significant future obligations with retired workers. This is specially critical in the case of GM. With more retirees than active workers in 2004—370,000 versus 290,000, GM’s healthcare and pension costs add \$1360 of overhead to each car produced. For Toyota and Honda, both non unionized, this figure is merely \$80-107/car (Roos, 2004).

Union contracts limit worker flexibility (salaries are essentially independent of the actual utilization factor of the factories) and make difficult or very expensive to reduce workforce via layoffs, making difficult to adjust manufacturing capacity quickly, hence the concern for achieving high utilization factors that dominates the industry. In an industry that already has excess capacity, GM has maintained artificially high production rates even in the midst of a recession.

### **Downstream: Channel Lock-In**

Traditionally, automobile manufacturers have relied on a vast network of dealers for product distribution. Dealerships are an effective way of distributing goods that require extensive customer assessment before purchasing, and local maintenance after purchasing. The first premise no longer holds in the Internet age – customers now obtain a wealth of information in the Internet that in the past was only accessible through the dealers.<sup>9</sup> The second premise remains true, but chains of vehicle maintenance services open the way to alternative ways for local customer support.

However, even though the stage may look to be set for manufacturers disintermediating their dealers using the Internet as a sales channel, and third-party support for post-sales support, regulation impedes manufacturers to effectively do it and sell directly to customers via the Internet—following Dell’s model.

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<sup>9</sup>As a reference, in interviews with dealers of Hyundai, Chevrolet, and Acura in the greater Boston Area conducted in April 2005, dealers estimated that 60-80% of the customers who had done substantial research in the Internet *before their first visit* to the dealership.

### 7.1.3 Capital Markets

Standard & Poor's estimates that the downgrading of GM and Ford's bond ratings will increase the cost of capital for these two companies and for their close suppliers. The situation is, at best, unlikely to change in the short term, and puts stress on GM and Ford to generate cash and minimize capital expenses; therefore, it is reasonable to assume that both companies will attempt to avoid capital-intensive changes in their supply chains, and favor incremental solutions over radical changes in the core.

### 7.1.4 Technology and Product Development Dynamics

#### Design cycles getting faster

For most automakers, developing a new vehicle model is a formidable endeavor that takes 3-4 years on the average—a huge improvement compared to the 8 years it used to take in the 80's, but still a long design cycle. A few automakers such as Nissan Motor Co. are known to have development cycles as short as 10 months for some of their models,<sup>10</sup> and General Motors reached 18-24 month development cycles for some of their models in 2003, with planned reductions toward 12 month cycle.<sup>11</sup> However, these cycles are still not widespread.

Physical limits to further design cycle reductions exist. Not only the vehicle, but the whole production system that manufactures it has to be engineered, and a car still has of the order of several thousands of different parts that need to be orchestrated across a network of suppliers. Therefore, the quest for shorter cycles will most likely imply more incremental changes and less radical innovation—largely what Japanese manufacturers have been doing so far.

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<sup>10</sup>Source: Standard & Poor's, see citeLevy:05.

<sup>11</sup>Gary Witzenburg, "Vehicle development view from the trenches: a look at the tricks and tools automakers use to squeeze time and cost out of new product Development Process," Automotive Industries, March 2003

## **Even greater modularity in the horizon**

In 1995, the top automakers in the US and Europe were adding 40% of the final value of the vehicles; in 2004, this figure has dropped to a mere 25%.<sup>12</sup> All the rest is provided by their suppliers.

Since the early 1990's we have seen a clear trend towards tier 1 providers delivering complete subsystems (or 'modules') to the assembly lines rather than plain components. Automakers attempt to reduce manufacturing complexity, and tier-1 providers struggle to improve their tight margins by offering more value-added functionality in their products and services.

Although modular design and subsystems, product platforms and commonality plans have been the norm of the decade, there are still some evident limits to modularity. Unlike a computer, some parts in the design of cars such as engines are still highly integral, and are not amenable to be managed as subsystems outsourced to different tier-1 providers.

However, technology advances in the horizon such as drive-by-wire, a technology that is expected to replace hydraulics in 8-10 years<sup>13</sup> promise to simplify car internals and take modularity to a next level. From the standpoint of Supply Chain Management, drive-by-wire has the potential to make a car look more like a computer: in the small, it will simplify inbound logistics and procurement; in the large, it may unbundle the market and make horizontal competition that nowadays is vertical.

## **B2B**

IT, and more specifically ERP and MRP technologies promised to tightly link manufacturers and their suppliers, but so far this has only happened at the tier 1 level. ERP implementations work much like point-to-point links, partly a legacy of the pre-Internet Electronic Data Interchange (EDI). Point-to-point is suitable for linking manufacturers with a few major tier 1 suppliers, but complexity becomes unmanageable when the network is extended to the thousands of providers in the rest of

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<sup>12</sup>Source: Handelsbaltt, as cited by Sachon and nana (2004).

<sup>13</sup>Source: 3DayCar Program.

tiers.<sup>14</sup>

The industry attempted a transition to a hub-and-spoke architecture in an attempt to increase scalability. In 2000 the Big Three merged their Internet exchanges and formed COVISINT,<sup>15</sup> the world's largest Internet-based marketplace. Ford and GM expected savings up to \$1,000 per car, but those never materialized. The reality is that only 33% of the tier 1 suppliers have resources to implement a large-scale e-business program, and only 13% use exchanges like COVISINT.<sup>16</sup> COVISINT's auction business ended being acquired by the online auction operator FreeMarkets (now part of Ariba, Inc.); the supplier management portals and data messaging services were purchased by Compuware.

### **Business-to-Customer (B2C)**

The web has provided the means for automakers to deal directly with the end customer for the first time. All the major automakers were quick in deploying Internet portals offering information and assistance for prospective customers, but dealers—fearing disintermediation, and supported by state regulation—have pushed back manufacturers in fully pursuing a complete B2C strategy.

Customer portals have been relegated to the task of showroom; however, out of the purchasing loop, customer portals have overwhelmed automakers with data, but little information. Clickthrough data from the portals is inherently biased, as prospective customers tend use automaker's portals as a showroom of the models, but they prefer independent sites to look for actual purchasing assessment. In addition, it is not always possible to correlate specific sales at the dealerships with clickthrough information, leaving the most valuable data out of the reach of the manufacturers.

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<sup>14</sup>See for example: Lawrence S Gould, "The Six-Hour Car: How IT Can Help Make It Happen" *Automotive Design & Production*, Volume 116, Issue 1, 1 January 2004.

<sup>15</sup>COVISINT stands for CONNECTivity, COLlaboration, and COMMunication; VISibility though the Internet, VISION of the future Supply Chain Management, and INTegration.

<sup>16</sup>Chris Moritz, CEO of SupplySolutions, provider of the i-Supply Service that is at the core of COVISINT fulfillment, as cited in Holweg and Pil (2004, pag. 126).



## Operations Support Systems

Holweg and Pil (2004, pag. 106) present IT as both an enabler and an inhibitor for an eventual transition towards a Build-To-Order model in the industry.

An order typically flows through three to five stages, namely:

**Order Entry** transfer from dealer to automaker, transforming the customer order into manufacturing codes and checking for constraints

**Generation of Bill-of-Materials** transfer to MRP and from there to suppliers

**Order Scheduling** transfer to a weekly or daily factory production schedule

**Order Sequencing** in-factory sequence of orders

**Outbound Logistics** transfer the post-built information to the distribution system  
– also called ”traffic control”

According to Holweg and Pil, most automakers’s information systems were originally designed for batch mode operation—which typically adds one day of delay per major information transfer in the process.<sup>17</sup> Therefore three to five days are added to the process just because of batching.

Transforming an information system designed with a batch, *push* logic in mind into one suitable to fully support a *pull* logic, would require a complete transformation—rather than an incremental update—if it is to happen in the short term. The problem is that the industry has a large installed base of legacy systems that can’t be easily phased out—for example, Ford maintains 350 million lines of custom code, supporting more than 2,500 applications.<sup>18</sup> In consequence, the current Operations Support Systems infrastructure also favors an incremental approach.

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<sup>17</sup>Transactions are typically recorded during the day and processed during the evening.

<sup>18</sup>(Source: Marv Adams, CIO, Ford Motor Company; presentation at MIT System Design and Management Program, February 2004).

### 7.1.5 Business Dynamics

#### Consolidation Upstream

The industry has been in a continuous consolidation process since 1998, when Chrysler merged with Mercedes-Benz to become DaimlerChrysler AG. In the meanwhile, Ford acquired Aston Martin, Jaguar, Land Rover, Volvo, and partnered with Mazda Motor Corp. GM acquired Saab, part of Daewoo, and acquired stake in Fiat SpA. If we were to filter the companies at the top of the financial structure of the automobile manufacturing industry worldwide, the global car manufacturing industry in 2005 would be reduced to barely GM, Ford, DaimlerChrysler, Renault, PSA Peugeot-Citroën, VW, Porsche, BMW, Honda, and Toyota.<sup>19</sup> These mergers and acquisitions reflect the increasing globalization of the industry. Competitors no longer are just US manufacturers, but global manufacturers that increasingly compete with local production—in fact, in the last decade Japanese and Asian manufacturers have been opening factories in the US at the same rate as the Big Three closed them (Roos, 2004).

Consolidations have also affected the auto-part supplier market as well. Take for example Dana Corporation; table 7.1 illustrates Dana's different acquisitions since 1977, the year Dana entered the auto-parts market, until 2003, the year that Arvin-Meritor, result of the merge of Arvin and Meritor in 2000, (unsuccessfully) attempted to buy Dana:

The story of Dana has been the norm, rather than the exception. Automaker's margins have been halving every 40 years since the 1920's, when a 20% margin was common.<sup>20</sup> Nowadays, Japanese manufacturers make about a 7%, European ones some 5%, and the Big Three less than a 3%.<sup>21</sup> As automakers attempt to compensate tighter margins by putting pressure on suppliers to reduce costs, suppliers—many times small and privately held—find themselves in an increasingly difficult situation, and get acquired, or merge in desperation. So far, they have managed to survive be-

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<sup>19</sup>See Holweg and Pil (2004, pag. 68) for a discussion of the complex financial structure of the automotive industry.

<sup>20</sup>"Perpetual Motion," *The Economist* 2 September 2004.

<sup>21</sup>Source: Hoovers

Year	Event
1977	Acquisition of Weatherhead Company (hoses, fittings, and couplings, US)
1992	Acquisition of Delta Automotive and Krizman (automotive aftermarket parts, US)
1993	Acquisition of Reinz Group (gasket maker, Germany)
1994	Acquisition of Sige (axles, Italy) and Sieber Heidelberg (industrial components, Germany), Tece (auto-parts distribution, Mexico), Tremec (transmissions, Mexico)
1995	Acquisition of several plastic and rubber makers
1996	
1997	Acquisition of Clark-Hurth Components (drivetrains), SPX Corporation (piston and cilinder lines)
1998	Acquisition of Eaton Heavy-Axle/Brakes, Echlin, and Federal-Mogul (auto-parts)
2000	Acquisition of Invensys Axle (axle manufacturing, UK)

Table 7.1: An example of supplier consolidation: Dana Corporation

cause auto production has been held at a record pace for years,<sup>22</sup> arguably artificially in some cases, such as for GM. However, the recent general production slowdown—consequence of oversupply of cars since late 2001—has endangered suppliers again and accelerated the consolidation process as orders freeze, production volumes drop, and with them volume discounts vanish.

While these dynamics affect mostly to small players, the size of suppliers experiencing difficulties—and even going out of business—keeps increasing.<sup>23</sup> In the long term, the wave bounces back to the automakers, who are the ultimate stakeholders. For example, in 2005 Ford had to issue a \$25 Million/month aid package for its former parts unit Visteon Corporation.<sup>24</sup>

## Consolidation Downstream

Consolidation also affects dealerships in the downstream supply chain, although the process is slower. There were 50,000 dealers in the US in 1950; by 2002, the number

<sup>22</sup>Susan Kelly, “Auto supplier shakeout set to accelerate.” Reuters News, 7 March 2003 (via Factiva).

<sup>23</sup>As of June 2005, Collins & Aikman Corp. is the largest supplier that has filed for bankruptcy, with \$3.9 billion revenues in 2004.

<sup>24</sup>Source: Standard & Poor’s (see Levi and Ferazani (2005)).

had dropped to 22,000.<sup>25</sup> Major chains include Auto Nation, with 400 dealerships, and United Auto Group and Sonic Automotive, both with about 200 dealerships. The decrease in dealerships is also in part due to the fact that automakers have tended to offer less franchises.

Growing in scale allows dealerships to pool risk and manage more efficiently the higher costs of inventory in the current push-based model—but also opens the possibility for larger dealership chains to open the Internet sales channel that regulation prohibited to automakers, thus enabling built-to-order customer sales, and laying out the path for a transition to a pull-based model.

### **The dynamics of excess capacity**

In 2002, GM's capacity utilization was 90%; in the first quarter of 2003, it increased up to a 91.1%, and originally had plans to reach 100% in 2005. Ford had even higher utilization—93%, and Chrysler lagged only slightly behind with a 89%.<sup>26</sup> High fixed costs at the factories and decreasing margins underlie this race for higher utilization factors.

Instead of attempting to solve the root of the problems—excess capacity and poor matching between what customers want and what is actually produced, the Big Three in general, and very specially GM, have maintained production rates artificially high during a recession. This policy has flooded the dealerships with inventory that will need even more incentives to be sold, further eroding profit margins (Holweg and Pil, 2001).

## **7.1.6 Customer Preferences**

### **More models and more possibilities for customization**

If we were to judge the evolution of customer preferences solely on the basis of automaker's product catalogs, we would probably conclude that consumers are demand-

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<sup>25</sup>Source: Plunkett's Automobile Industry Almanac, ISBN: 1-891775-76-6.

<sup>26</sup>Eric Mayne, Brian Corbett, and Kevin Kelly. "Detroit's bitter pill," Ward's Auto World, Jul 2003, vol.39, issue 7.

ing a far more diverse range of products than ever before. Not only a wide variety of new car categories have been introduced including cars that didn't exist in the past—such as SUV's, customers are given a wider range of possibilities for customizing the product. In the 1990's manufacturers had doubled the number of models they were offering in the 1960's (Holweg and Pil, 2004, pag. 164), and only from 1997 to 2002 the number of models increased 50%<sup>27</sup> When permutations of body style, engine, color, trim, and options are configured, the effective number of potential configurations grows astronomically. Regardless whether the market was actually demanding such a huge variety or not, model proliferation has now educated customers in having an almost infinite variety to choose from.

### **Product life cycles**

Sales tend to slow down as the average age of models grow. In the US, cars traditionally go through minor updates every year, and this seems to be the trend that will dominate worldwide in the next years. In Europe, minor revisions used to be carried after a few years, but some manufacturers have already announced their intent to keep model average age below three years.<sup>28</sup>

### **Demand predictability**

Demand volume exhibits seasonality. Sales are concentrated during the spring-summer season, and linked to local cycles such as plate registration seasons (which may determine the residual value of the car in the long term), or payment of company bonuses. In the US, sales tend to drop by the end of the year, as more customers prefer to wait for next-year's models. Sales also experience "hockey-stick" effects by the end of the months due to rush to fulfill sales objectives.

The impact of these cycles has been limited, not only because they are all known phenomena, but also because nowadays dealerships have abundant stock to manage demand increases. However, this kind of seasonality can pose problems for an

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<sup>27</sup>Source: Plunkett Research.

<sup>28</sup>"Fighting Back," The Economist, 4 September 2004.

eventual migration toward a pull-based, build-to-order system, where manufacturing activity attempts to follow the demand.

Demanded features are to some extent linked to external factors, such as general economy growth or soaring fuel prices (which favors smaller cars in the low and mid-range series). In this aspect, they are foreseeable and evolve at a manageable pace given the current product development cycles. Nonetheless, product misses still happen from time to time, such as Ford and GM's lack of adoption of diesel engines in Europe, and will become worse as product introduction rates increase.

### **Demand Steering considered harmful**

End-of-season rebates and incentives not only hurt margins: they also distort demand information by creating artificial sales cycles, and educate customers in the practice of bargaining at models available at the parking lot, rather than attempting to get models that actually fit their needs at a full price.

### **Service level expectations**

US customers are among the most demanding customers of the world in terms of service levels. Customers are not willing to wait the time it takes for a customized car to be built to order; instead, they are willing to settle for a similar model if it is available in the parking lot—at the price of lower margins due to “underselling” and incentives. GM estimates that 95% of their sales come directly from vehicles in stock at the dealer's parking lot.<sup>29</sup> In contrast, close to 50% of the cars are already built to order in Europe, and over 60% in Japan (Holweg and Pil, 2004).

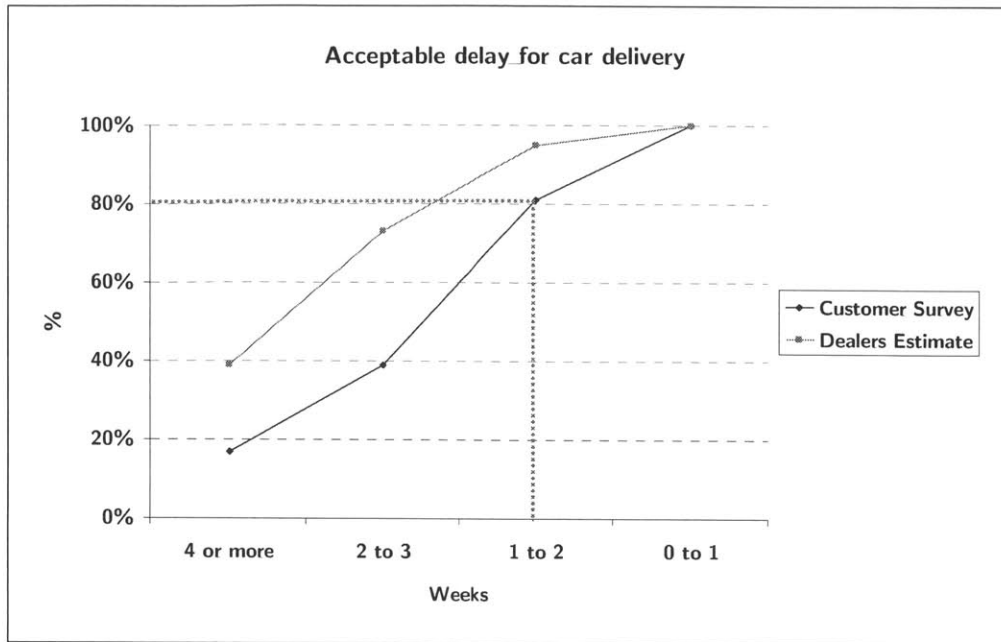
Aside the culture of “instant gratification” dominant in the US, lead times are to blame. A survey of the 3DayCar Program<sup>30</sup> of new buyers and dealers in the UK, where only 33%<sup>31</sup> of the cars are made to order, found that in order to satisfy most of

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<sup>29</sup>Source: interview with Clifford Hodges, Director VSSM Demand Sensing at General Motors, March 2005. Holweg and Pil (2004) report a similar figure for the US car manufacturing industry as a whole.

<sup>30</sup><http://www.3daycar.com> (Accessed August 9, 2005)

<sup>31</sup>1999 estimate.



Source: adapted from 3DayCar Dealer Survey, 12/1999 [www.3daycar.com/mainframe/sponsors/conference/dec00conf/newbuyerres.pdf](http://www.3daycar.com/mainframe/sponsors/conference/dec00conf/newbuyerres.pdf) (Accessed August 5, 2005)

Figure 7-2: Customer willingness to wait for a custom car

the customers, delivery delays must be kept under 2-3 weeks – way below the average six weeks that it takes for a custom car to be delivered in Europe, not to mention the 10 weeks it would take in the US (Miernicki and Holweg, 2004).<sup>32</sup>

## 7.2 Strategy

Model proliferation is to a great extent an unexpected consequence of two strategies that the Big Three have pursued in the past decade:

- Segment markets much more finely, and introduce new vehicles to target niche markets.
- Offer extensive customization options in all the vehicles as a way to differentiate their commercial offerings.

<sup>32</sup>The study also found large differences in perception of the ideal time to deliver a new car between customers and dealers; the most significant difference was that dealers thought that a delivery time of over 4 week would be reasonable for 40% of the customers, where in reality it is closer to a 17% (see Figure 7-2).

None of these options is intrinsically bad, but GM, and in general the Big Three, have attempted to pursue both at the same time, in the midst of a intense competition in cost, and with a supply chain that is not suitable to support any of these strategies.

### **Model Proliferation**

When manufacturers feel pressured to offer models to compete one-by-one with all the competitor's offerings in every conceivable segment, the market gets fragmented and brands become increasingly confusing for the customer (Roos, 2004).<sup>33</sup> Recent examples include Volkswagen, traditional brand in the mid-range, entering the luxury market with the Phaeton, or BMW and Mercedes moving in the opposite direction with the Series 1 and the A Class respectively.

Brand equity dilution can be avoided by releasing third brands – such as BMW's Mini and Mercedes's Smart. However, these niche markets are still too small to be profitable given current car development and manufacturing costs, and an interesting dynamic becomes apparent: automakers start cooperating in joint ventures to develop and manufacture common vehicle platforms, so that development costs can be split among the partners and render profitable small-volume models—such as the Toyota Aygo, the Citrën C1, and the Peugeot 107, all based on the same platform, developed jointly by Toyota and PSA, and produced on a shared factory in the Czech Republic.

### **Over Customization**

Product customization—providing the customer wider product variety to choose from, and trying to match his unique needs with a more personalized offer—has the potential to increase both manufacturer's margins and customer satisfaction, but variety has important implications from the standpoint of the supply chain that must be carefully assessed.

As of today GM's supply chain is driven by a forecast and relies on stocking inventory at the dealerships; in such a situation, every single additional degree of customization does nothing but increase the probability of mismatch between what

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<sup>33</sup>See also "Fighting Back," *The Economist*, 4 September 2004.



the customer actually wanted, and what is sitting in the dealer's parking lot<sup>34</sup>—and mismatches are paid with discounts that drain profitability.

Too much external variety in a push downstream supply chain increases the likelihood of producing the wrong car, sending it to the wrong dealership, or delivering it at the wrong time. If high external variety is to be offered, either the downstream supply chain transitions to a pull-based mode, or final customization pushed as far away downstream as possible—ideally at the dealerships, but this is only feasible for a limited number of options, such as the stereo equipment or on-board computers.

### **Competition in Cost**

Competition in cost has actually degenerated in a deadly practice to push inventory the customer through incentives and discounts. In this way, GM uses rebates as a way to compensate the limitations of a production system that can't avoid building inventory.

## **7.3 Product Development**

### **Faster model introduction, but still long cycles**

Model introduction rates in the US automotive industry have been accelerating since 1970, from an average of one new model every 7-8 years, to one new model every 4-5 years in 2000 (Holweg and Pil, 2004, pag. 175).

Nowadays, it takes GM about 36 months to get a new vehicle into the showrooms, divided between about 12 months of concept design (figuring out what sort of vehicle it should be made and making the business case for it), and 24 months of actual design and engineering.<sup>35</sup> The whole process is costly, and can easily go over \$1 billion.

Faster product introduction stresses the supply chain by demanding structural

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<sup>34</sup>Refer to Schwartz (2004) for a discussion of how excess variety can actually yield lower customer satisfaction by amplifying the perception of mismatch between the customer's wants and the product finally acquired.

<sup>35</sup>Bob Lutz, GM's Vice Chairman of Global Product Development in "Fighting Back," *The Economist*, 4 September 2004.

changes to be made more often, but in addition it imposes fundamental changes to the problem of forecasting demand: in slow *clockspeed* products, demand risk is dominated by seasonality and the natural variability of the demand signal; in fast *clockspeed* products, market acceptance of the product dominates demand risk, and it is much more difficult to manage with supply chain management-centric techniques.

## Incremental and Radical Product Innovation

Japanese manufacturers have been steadily introducing new models regularly every 4 years on the average since 1970. A major difference between US and Japanese product introduction strategies is the level of novelty introduced in each new model. Japanese manufacturers follow a discipline of incremental innovation and rarely release all new products;<sup>36</sup> in addition, changes are scheduled to avoid introducing two major changes at the same time – such as a change in the power train and a change in the body. In contrast, GM has been introducing more “all new” cars, a policy that is attributed to have caused more harm than good in the last years: in 2004, GM registered 11.6 million vehicle recalls, most of them attributed to immature car versions.<sup>37</sup>

## Managing Internal and External Variety

As we saw in chapter 5, *External variety*, the breadth of product choices that are offered to the end customer, has a severe impact on the cost structure of the downstream supply chain, as it decreases the level of risk pooling. It is driven by customer preferences, and ultimately determined by the firm’s competitive strategy. In the case of GM, the strategy has been offering great flexibility in model customization.

Product architecture links external variety to *internal variety*—or the variety that manufacturing has to manage, e.g. number of different trims, engines, etc. The right product architecture can efficiently decouple external variety from internal variety, and therefore enable high external variety with a minimum amount of internal variety.<sup>38</sup> Two complementary strategies can be used for this purpose:

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<sup>36</sup>James E. Harbour, “Why GM’s profits really hit the wall,” The Detroit News, 27 March 2005.

<sup>37</sup>James E. Harbour.

<sup>38</sup>Internal and external variety are closely related to the concepts of mediation-dominant and

1. Standardization, Commonality Plans and Product Platforms – using standardized parts and subsystems and sharing them across product families.
2. Modular Designs – encapsulating functionality in subsystems that can be interconnected by means of standardized interfaces.

## **Commonality and Product Platforms**

Commonality and Product Platforms spread product development sunk costs across several different models, and decouple the development speed of the base functionality—the platform—from that of the end product, improving economies of scale, and enabling economies of scope and faster product introduction.<sup>39</sup> From the standpoint of Supply Chain management, platforms enable greater manufacturing flexibility. This can be used to implement a build to order strategy, provided that the fulfillment supply chain is responsive enough to support it.

### **Modular design**

Modular designs make easier to outsource the development of full subsystems to external providers, hence enabling new forms of component procurement. They also reduce complexity, and with it, assembly time – enabling shorter manufacturing cycles. More importantly, from the standpoint of Supply Chain Management, they decouple internal variety from external variety, and therefore allow to offer a wider range of product choices to the end customer with the same amount of internal variety.<sup>40</sup>

The dilemma now is how to decide what features to standardize in the platform, and what other features to leave out of it. Every feature put into the base platform reduces both internal and external variety, and therefore reduces both manufacturing costs and inventory risk. At the same time, it commoditizes the feature, and therefore limits its profit margin. In general, it will be cheaper to move popular features into

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production-dominant variety introduced in chapter 5.

<sup>39</sup>As long as the the new product is based on an incremental improvement, rather than a radical change in the design.

<sup>40</sup>Note that commonality plans can be used for different subsystems, and not only for the product platforms.

the base product, rather than offering them independently; for example, in a study of a major vehicle manufacturer Holweg and Pil found that if more than 60% of the customers requested ABS, it was cheaper to have a single base model with ABS than independent ABS and non-ABS models (Holweg and Pil, 2004, pag. 172).

## 7.4 The Production System

### 7.4.1 Planning and Forecasting

At the heart of GM’s production system—and in general to the Big Three—we find a complex system for scheduling and sequencing orders. Overall, it is a centralized, forecast-driven, push-based production system designed to maximize manufacturing capacity utilization.

#### Initial forecasts

Production schedule at the factories is broken by brand (or more finely if the brand is very complex – as it commonly happens with trucks) each month. Production capacity per brand is then allocated between GM’s different business types, such as commercial fleets, engineering, internal uses, and retail dealerships.<sup>41</sup>

#### Initial inventory allocation to Dealerships

Dealerships are the most important of these categories, and also the most challenging from the standpoint of the supply chain. Capacity is allocated to them on the basis of short-term (3 months) and long-term (12 months) dealer’s sales history, as well as the dealer’s *availability* (product mix in the dealer’s parking lot). The number of best-selling configurations in inventory, and the total number of configurations in inventory are used to assess the “inventory quality”, in an attempt to equalize the dealers’s availability and sales rate.

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<sup>41</sup>GM has a total nine of these businesses.

## Consensus and Variance Processes

Dealers connect regularly to GM's dealer portal and check the initial production share they have been allocated by GM, and make corrections if necessary. This process is called the *consensus* process. GM uses then the updated quantity to revise the manufacturing schedule and plan to increase or reduce production accordingly; if the manufacturing schedule is running too short of production, however, the dealers are asked to reconsider additional orders, so that capacity objectives can be met. This process is called the *variance* process.

### Weekly ordering

Once the gross monthly quantities per brand have been agreed, the dealer proceeds placing orders for the specific configurations required every week. Orders are not immediately approved; instead, they are submitted *for consideration*, so that GM can verify if they are compatible with current production constraints, which include both capacity limits, and component supply availability. For example, if too many orders for a certain model with sunroof are received, and the production lines can't cope with them, some of the orders won't be approved. As soon as the order is approved, it is frozen and no further configuration changes are possible.

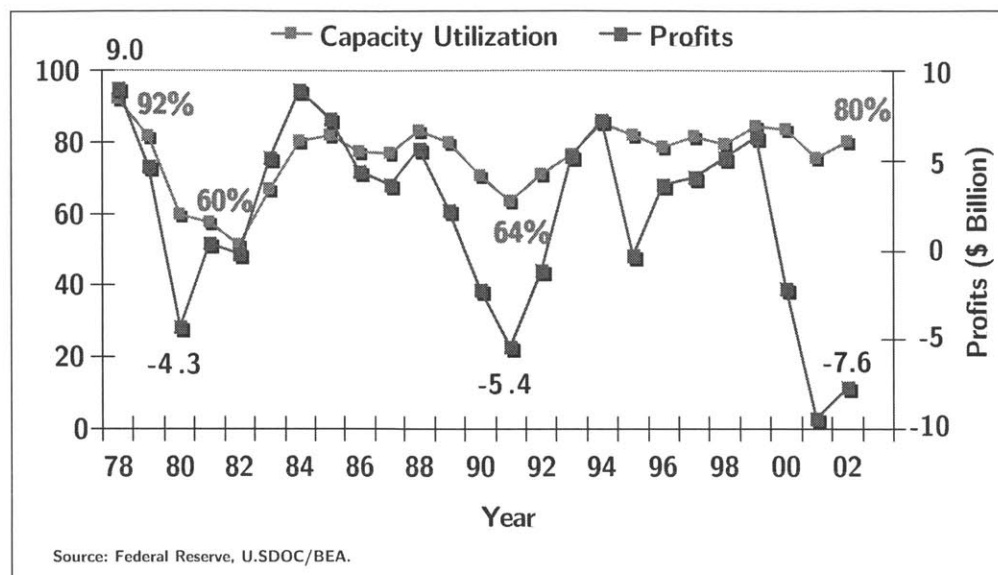
The whole ordering and manufacturing process takes between 30 and 45 days, on top of which we must add 7-12 days of transportation to the dealership<sup>42</sup>—much longer than the target 2 weeks presented in section 7.1.6. Interestingly, out of these 30-45 days, only 24-36 hours are devoted to actual manufacturing; the rest of the time is spent in production planning, scheduling, and sequencing.

### 7.4.2 Efficiency

High capacity utilization used to be a synonym of profitability in the US Auto Manufacturing industry since 1970. As soon as capacity utilization would get close to

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<sup>42</sup>These figures are similar to those reported by Holweg and Pil (2004, pag.44) in a study of car manufacturers in the UK.



Source: David E. Cole, “The Auto Future: Fast, Fun and Scary,” presentation at the Federal Reserve Bank of Chicago, Detroit Branch, 3 November 2003

Figure 7-3: Capacity utilization and profitability in the US Auto Manufacturing Industry

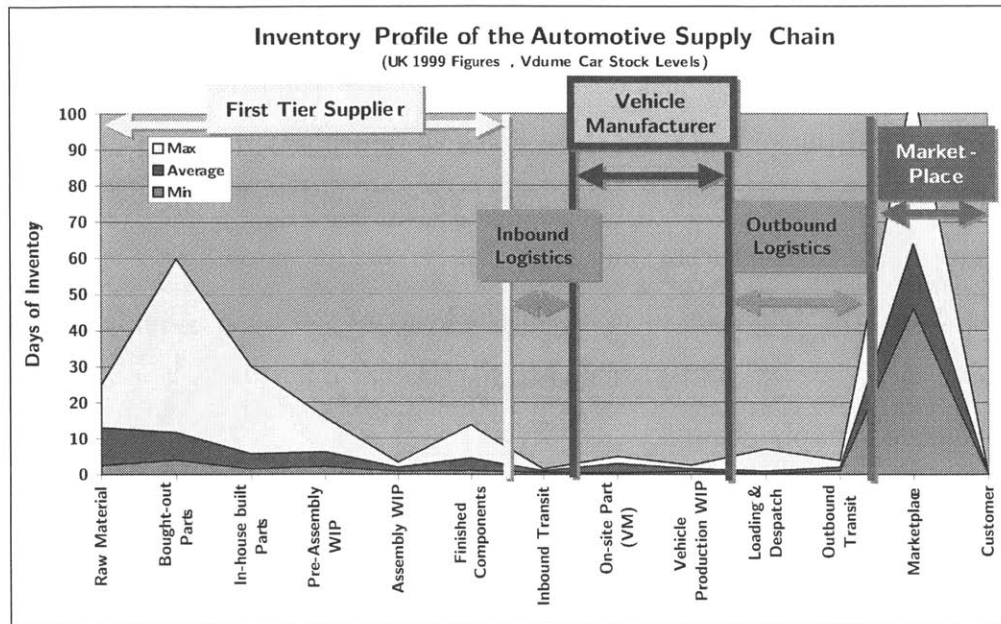
60-65%, profits would drop, so that traditionally the whole production system—starting with factory manager’s bonuses—had been crafted for production volume and efficiency.

### High utilization factors no longer ensure profitability

The link between capacity utilization and profitability has disappeared in the last decade. Figure 7-3 reproduces results from the Center for Automotive Research (CAR) that show how since the mid 90’s, the US car manufacturing industry has maintained utilization factors over 80%, and yet profits have dropped to historic minimums.<sup>43</sup>

The underlying assumption was that *everything* produced would eventually be sold. That might be the case during the golden years of the industry, but not today. At an average cost over \$3,000 per car in incentives to get rid of excess inventory,

<sup>43</sup>David E. Cole, “The Auto Future: Fast, Fun and Scary,” presentation at the Federal Reserve Bank of Chicago, Detroit Branch, 3 November 2003. URL [http://www.chicagofed.org/news\\_and\\_conferences/conferences\\_and\\_events/files/geography\\_of\\_auto\\_production\\_the\\_auto\\_future\\_fast\\_fun\\_and\\_scary.pdf](http://www.chicagofed.org/news_and_conferences/conferences_and_events/files/geography_of_auto_production_the_auto_future_fast_fun_and_scary.pdf) (Accessed 21 August 2005); and “Fighting Back,” *The Economist*, 4 September 2004.



Source: 3DayCar Program Presentation, December 2001 <http://www.3daycar.com/mainframe/sponsors/conference/dec01conf/Synthesis.pdf> (Accessed August 6, 2005)

Figure 7-4: Distribution of inventory along upstream and downstream supply chains

achieving higher utilization factors by producing models that no buyer will buy shall be dismissed as a harmful practice.

## Supplier Flexibility

Suppliers of components can take orders with only 2-3 weeks notice; they operate at a certain nominal capacity rate agreed with GM, and they must provide flexibility to increase the nominal capacity rate up to an additional 15%.

## Lean manufacturing, revisited

Holweg and Pil (2001) point how misinterpretation of Lean Manufacturing principles has led to an overzealous focus on the factories. Figure 7-4 reproduces the results of a study conducted by the 3DayCar program showing how factories have indeed become efficient at the expense of other parts of the system where inventory accumulates—namely suppliers, and dealerships.

This kind improvement is an illusion: in the short term, upstream suppliers will

modify their cost structure to pass the cost of inventory back to the manufacturer. The manufacturer can push back on suppliers, but that won't solve the problem—just postpone it until the supplier runs into financial difficulties that will ultimately end affecting the manufacturer. In the same way, sales incentives will be required to push excess inventory, hurting profitability.

To sum up, the definition of *waste* at the heart of the Lean Manufacturing principles has to be revised and broadened to include not only the factory floor, but the whole extended supply chain.

## 7.5 Downstream Supply Chain

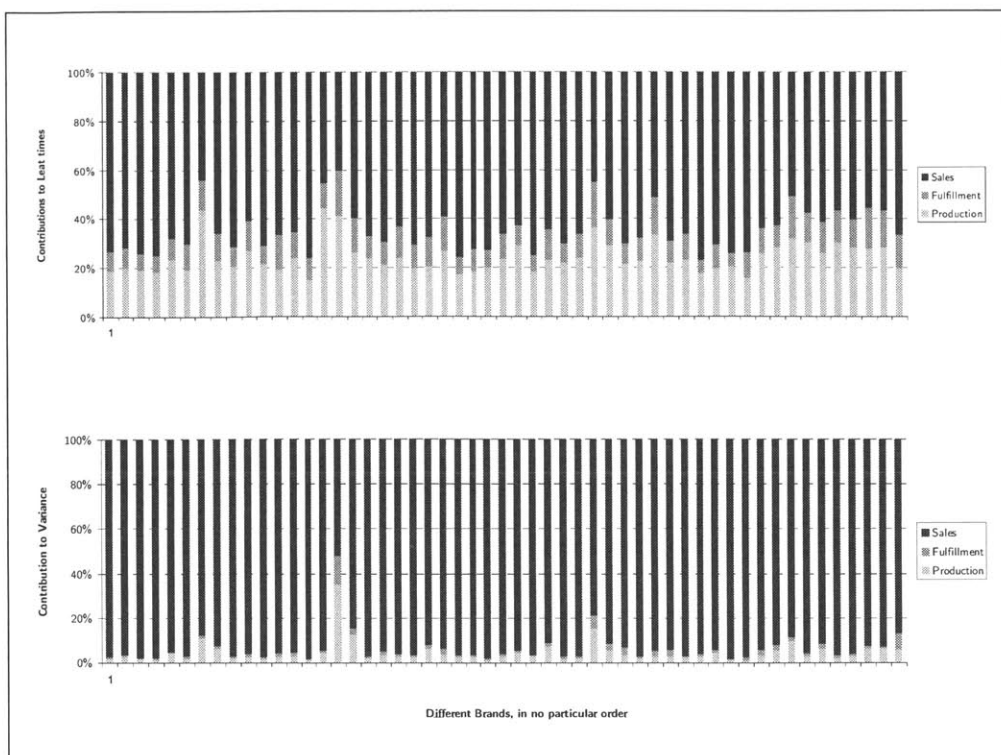
In terms of order to delivery cycle times, the downstream supply chain accounts for more than two thirds of the complete order: it takes about 30 days to produce a car, some 10 days to distribute it, and over 90 days to sell it from the dealer's parking lot. Differences are even more extreme when variance is taken into consideration—manufacturing, and also outbound logistics are very regular and predictable compared to the time it takes to sell the vehicle. Figure 7-5 breaks down the average end-to-end cycle times for a number of GM brands, as well as their respective contributions to variance.

Figure 7-6 depicts the order, manufacturing, delivery, and sales timing of a sample dealership; preallocation, consensus and variance have been omitted from the graph.

### Demand Sensing

GM gets the pulse of the market through dealer's order and sales data, in the so-called "Demand Sensing" process. This information is processed by GM, used in the volume allocation process, and then shared with the dealers to help them in their own ordering process. Dealers can access a report with the configurations that are turning faster and selling larger volumes in their zone—although the usage of these data by the dealers varies greatly.





Source: dataset provided by GM

Figure 7-5: Breakdown of end-to-end lead times

## How the system distorts demand information

In theory, in the order to delivery ordering process dealers own the stock in their parking lots and order freely following their best estimation of what the market demands. In practice, neither the dealers strictly “own” the stock in their parking lots, nor they order freely.

First, GM has a significant stake in the dealer’s parking lots. The dealers get a 90 days grace period to pay the cars they have received. If the car is sold after the 90 days, the dealer will pay the price of the car plus the interest accrued during the excess days. If it is sold in the first 90 days, no interest will be charged. Furthermore, in addition to possible dealer rebates, GM issues general end of season discounts to sell slow-moving inventory stuck at the dealerships. End of season discounts have a especially negative impact on GM’s margins because they can’t be applied selectively—they must be applied to the whole country.

Second, dealers can use the consensus project to make changes in the quantities

preassigned by GM; however, in case of production schedule unbalance GM will attempt to push the dealer to take additional orders during the variance process—and the dealer is likely to accept the deal “to keep the relationship” with GM.<sup>44</sup> Aside pure partnership loyalty, the dealers have a good incentive to take these extra orders: they know that GM will issue customer discounts at the end of the season for these models stuck in the market, so that everything will get eventually sold.

This policy distorts any demand information from the market, as everything that is produced is ultimately sold.

### **How the system distorts alignment**

A less obvious implication is that it distorts the responsibility for the accuracy of the forecast: in theory, dealers are free to make their own demand estimates, and they experience in first person the consequences of making bad forecasts, but when GM starts pushing vehicles to the dealers it is limiting their freedom to order whatever model they believe will sell, but by later issuing customer discounts to correct the mistakes it is also limiting the demand estimation risk the dealers bear. In short, the push system has displaced the authority, but also the liability.

## **7.6 Discussion**

GM represents the essence of a push-based production system and supply chain. Large capital investments in the production system become a trap as manufacturers attempt to compensate them by producing *more* instead of producing less—as Zara does—and remind us that efficiency is not necessarily linked to profitability, and that while mass production is the most effective production system in presence of unlimited demand, it is unsuitable in presence of oversupply, global competition, and more selective customers. Production system and supply chain flexibility must be properly valued.

The dynamics of disintermediation present in the distribution channel, and the

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<sup>44</sup>Dealer in the greater Boston area, interview conducted in April 2005.

tension between dealers's and automaker's interests present a case for the need of a broader, end-to-end, systemic view of the supply chain: Who is actually the owner of the inventory piling up on the dealerships? Do dealers have enough incentives to rotate inventory faster than every 90 days? Who bears the risk? Are rewards aligned with the risk? This systemic view is also needed to understand the implications of changes in parts of the supply chain in other parts of the system, and more specifically to learn to see beyond the factories, and to beware of killing suppliers. In short, to seek global optimization across the supply chain.

The product development process reminds us that end demand variability must be analyzed in terms of the scale of the product introduction rate—faster product introduction rates will make market acceptance the dominant concern.

Paradoxically, unless a way is found to manage customer's expectations of service level, if customers keep expecting to get their cars from the dealer's parking lot, a push-based downstream supply chain seems the most appropriate supply chain for GM in the US.

Product variety, Alfred P. Sloan strategy of "a car for every purse an purpose" beat Henry Ford's "any color, as long as it is black" in the 60's. From there to the 55 million possible configurations of the Opel Astra IV GM has lost something on the way.<sup>45</sup> It is hard to justify that general purpose, volume cars such as the GM Impala sold less than 10 different units per configuration in the US in 2004.<sup>46</sup>

In order to illustrate the magnitude of the mismatch, Figure 7-7 depicts the total volume of sales of different GM models sold in the US in 2004 vs. the total number of different configurations. The 100% variety line would represent models that sells all different configurations. The 5% variety line would represent cars that sell on the average 20 units per configuration. What is revealing in this graph is the number of high volume cars that also exhibit high variety. Volume cars can't be built to order with GM's current supply chain, and they tend to have tight margins that leaves little

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<sup>45</sup>The Opel Astra IV had 55,425,024 possible configurations; that is actually almost nothing compared to the 1,278,852,000 different variations of the 1983 Ford Sierra, not to mention the 3,933,000,000,000 net possible variants (taking combination restrictions into account) of the Mercedes E-Class (Holweg and Pil, 2004, pags. 165, 168, 169).

<sup>46</sup>Source: GM.

room for profitability if sales incentives need to be used to compensate supply-demand mismatches.

In contrast, Asian and Japanese manufacturers use less brands and offer much less variety – for example, a typical Toyota vehicle may come in only three basic options. Interestingly, this may be due to historical reasons: in the past, Toyota and other Japanese manufacturers exported their vehicles from Japan; long delivery lead times didn't allow for strategies other than building to a forecast, and therefore bundling as many options as possible in the base models had the advantage of simplifying production and logistics significantly. In short, Asian automakers were putting more options on the base platforms to overcome problems with lead times (Koudal et al., 2003).

Figure 7-8 presents a Pareto diagram of a high volume, medium-low variety brand, and figure 7-9 a high volume, high variety brand. In both figures we can observe a long tail of models that sell just one unit. In a pull-based system, this long tail would typically contain custom cars made to order, that therefore turn very fast; however, in a push-based system with a very sparse distribution network and limited transfers between dealerships, this long tail is dominated by supply-demand mismatches, as evidenced by the fact that for the subset of cars that sell just one unit the mean time to turn doesn't decrease.

GM tried to reduce the number of variants in the past without success. Dealers complained and the whole initiative had to be rolled back. According to GM,<sup>47</sup> the dealers's argument was that by reducing the number of options, GM was also reducing the dealers's profits from premium options and differentiated service.

In a closer inspection, however, the problem may be more complex. During informal interviews to dealers in the greater Boston Area in April 2005 we found that more variety and less options offered in bundles not only make the ordering process more cumbersome for the dealer, but also make more difficult to explain the models to the customers, and ultimately close the deal. According to the dealers, a reduction in variety could indeed be beneficial for their business.

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<sup>47</sup>Source: Tina Laforteza, GM Strategic Initiatives.

What can explain then the dealer's reluctance to option bundling, model proliferation and variety reduction in general? First, if everything is bundled, and for the customer everything gets reduced to choosing between 3-4 major options, dealers they are diluting the value of the service they offer as a dealers, essentially reducing it to after-market sales; more importantly, they are setting themselves for being disintermediated by Internet sales.<sup>48</sup> Second, model mismatches do not affect equally to dealers and automakers; not only is the automaker, not the dealer, who bears most of the cost of the sale, the dealer can actually recover part of the rebate offered by the manufacturer by pushing high-margin accessories and dealer-provided options: the incentives are not completely aligned.

### **The right Supply Chain for GM**

Given the amount of variety that the automotive industry must support nowadays, and given the fact that this variety is not likely to decrease, thinking in terms of the framework proposed in chapter 5 one might be tempted to think that two models could work for the automotive industry:

- A Push/Pull model, where a base car is made to forecast, transported to regional distribution centers, and then customized at that point.
- A Pull/Push model, where cars are made to order, but batched for transportation (a pure pull model would be unrealistic given that a car is a bulky product that does not accept individual delivery).

The problem with the first model is that by nature, the number of features that can be realistically postponed is limited, and those that are not, such as the sound system or the wheels, can be configured at the dealership. Even Honda in Europe, known for having transformed its distribution centers in “service centers” where the final customer customizations are executed does only implement basic features.

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<sup>48</sup>So far, the impact of Internet sales has been limited, mainly due to regulation impeding automakers to sell directly to customers. However, the situation may change as large dealer chains start pushing their online stores.

The second model is essentially the one proposed by advocates of Build-to-Order (BTO) car manufacturing: cars would be assembled in the factories according to a customer order, then batched for transportation and delivery. BTO fits the model naturally, because it allows to manage as much external variety as needed at the factory floor – the variety that is causing the problems. However, the immediate question is: if the fit is so good, why nobody has actually implemented it yet? as discussed, lead times are the main obstacle. It is simply impossible to implement such a system if current lead times are not improved. But there are other problems: such a system would find strong opposition downstream from dealers fearing disintermediation, and it would disrupt current production planning upstream as well. Furthermore, it would require to take substantial risk and capital investments that GM would not be willing to take in its current situation. In short, while BTO might be the ideal model, the transition from the current push system will require an intermediate model.

### 7.6.1 A Transition Model

This section explores two specific actions as part of a transition model aiming at the gradual transformation of the current, push-based model into a pure pull-based model.<sup>49</sup>

- Align product variety and supply chain characteristics: if it is not possible to change the supply chain, change then the product design.
- A change in the demand sensing process: if the push system is so sensitive to the demand forecast, improve it – and set the mindset for faster demand response.

### Rationalizing Variety

Figure 7-10 presents a possible strategy for managing configuration variety and model proliferation at the product design level: split volume models from speciality models.

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<sup>49</sup>This model is based on the qualitative analysis performed throughout this chapter, and it is therefore largely speculative—it provides a working hypothesis that must be validated with additional quantitative analyses.

- A limited number of volume configurations can be produced massively following a pure push model. For these configurations, options would be conservatively bundled in the base models, providing a small subset of feature-rich cars aggressively priced and with high availability at the dealer's parking lots. Such an approach would not only reduce production costs because of production standardization, but it would also reduce mediation costs because of risk pooling downstream. Automaker-provided sales incentives shall mainly target these models.
- Dealers would also be allowed to order non-commoditized models without any constraint. Virtually unlimited variety would be allowed here. However, the dealer—not the automaker—should bear most of the risk of the order. These models would be produced on demand, and priced at a slight premium to account for the additional value of customization. This strategy will decrease variability in demand, allow for smaller stocks, which in turn will help to create faster demand sensing cycles. If the market price does not cover costs, the production of the model should be stopped and the losses realized, rather than production be pushed to the market.

In order to minimize dealer reluctance to the new model, incentives must be generous for commoditized models, and an extra effort must be done to push as many final customizations as possible to the dealerships. For these customizations, components such as sound systems or GPS navigators can be pooled centrally and sent to the dealerships on-demand. We would therefore have a push-based system for a few base models, and a pull-based system for the customizations.

### **Improving Demand Sensing with minimal changes**

As development cycles accelerate, quick demand sensing becomes increasingly important. Nowadays, the metric in use—the average time to turn—can be misleading:

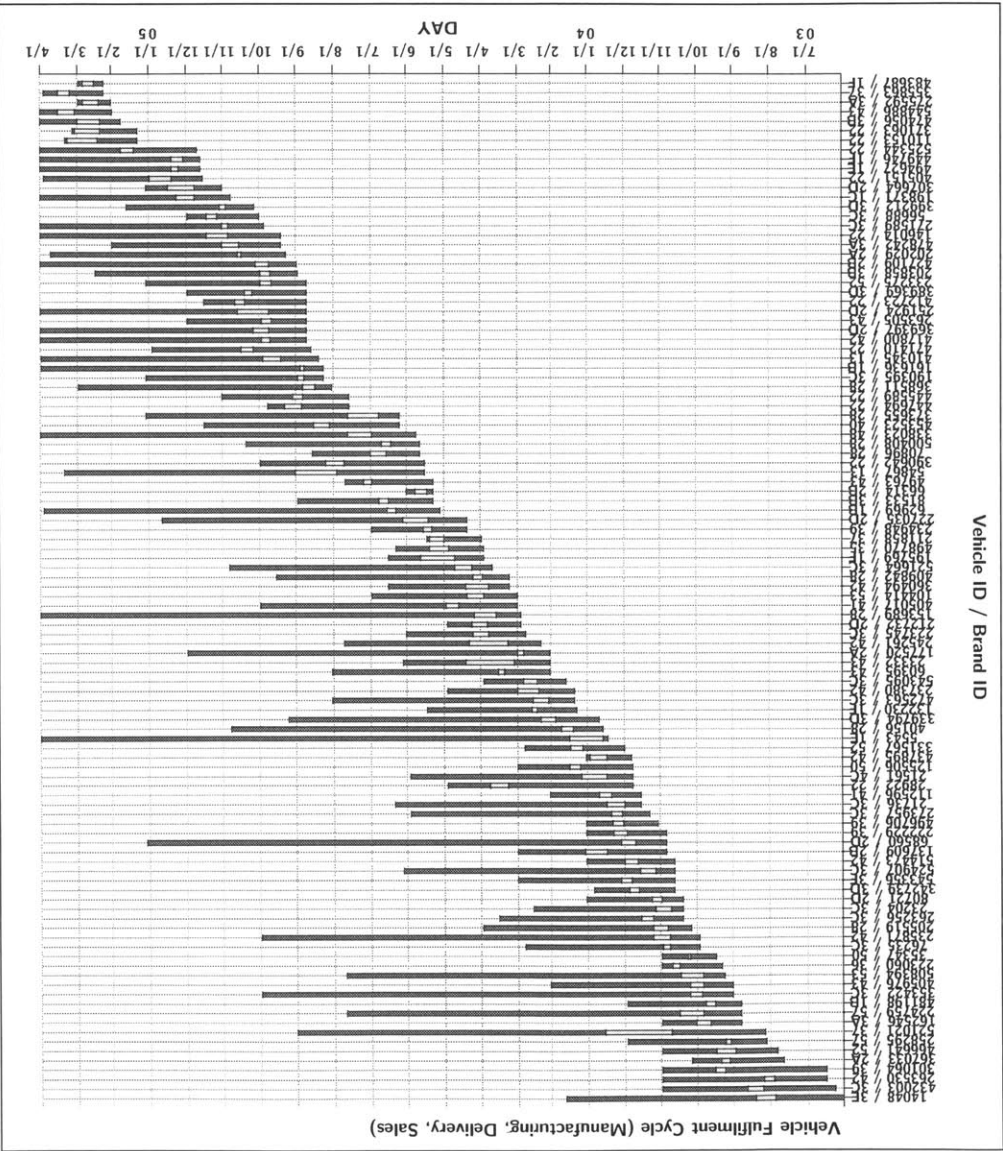
- It is too easily fooled by extreme values, and a few misplaced cars can make look a good selling model worse than it actually is.

- It is biased and detects problems too late. It ignores unsold cars waiting in the parking lot until they are sold. As a consequence, as we get close to end-of-season sales, the average time to turn tends to grow.
- It is not sensitive enough to detect changes, in the flow of sales, especially sudden increases of demand.

We propose an alternative metric—inventory velocity—to measure market pull. Inventory velocity is calculated by averaging the inverse of the time between consecutive sales of a specific configuration in a specific geographic region. Figure 7-11 compares the results provided by Time to Turn and Inventory Velocity.

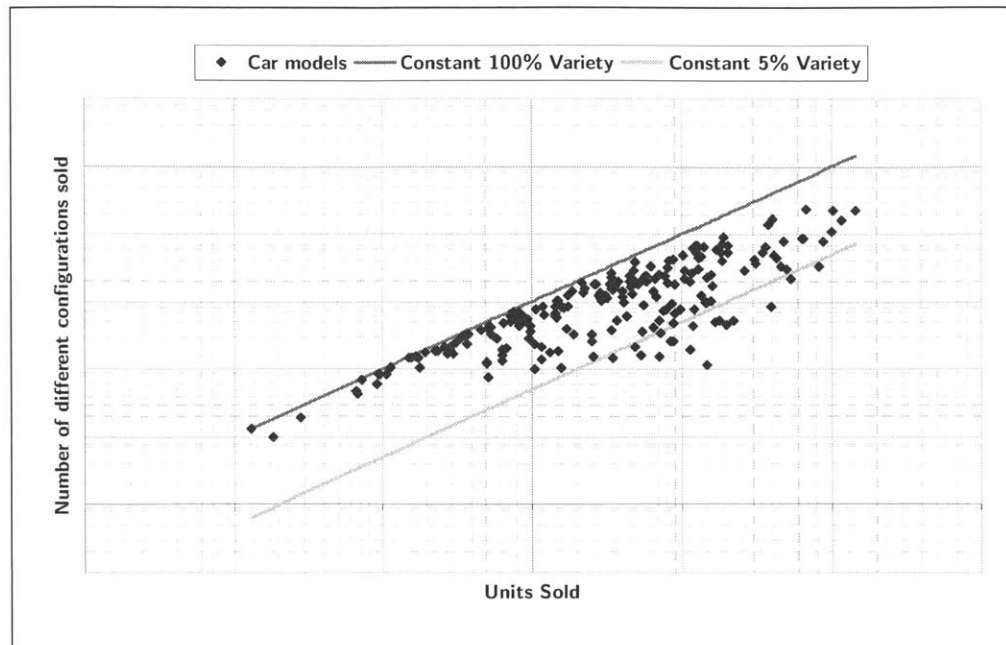
Inventory velocity is less biased and better suited to detect sudden changes in the flow of sales. It is also aligned with what actually matters for GM—having a steady, predictable revenue stream. It also has the advantage that it naturally filters out those models that are selling better.





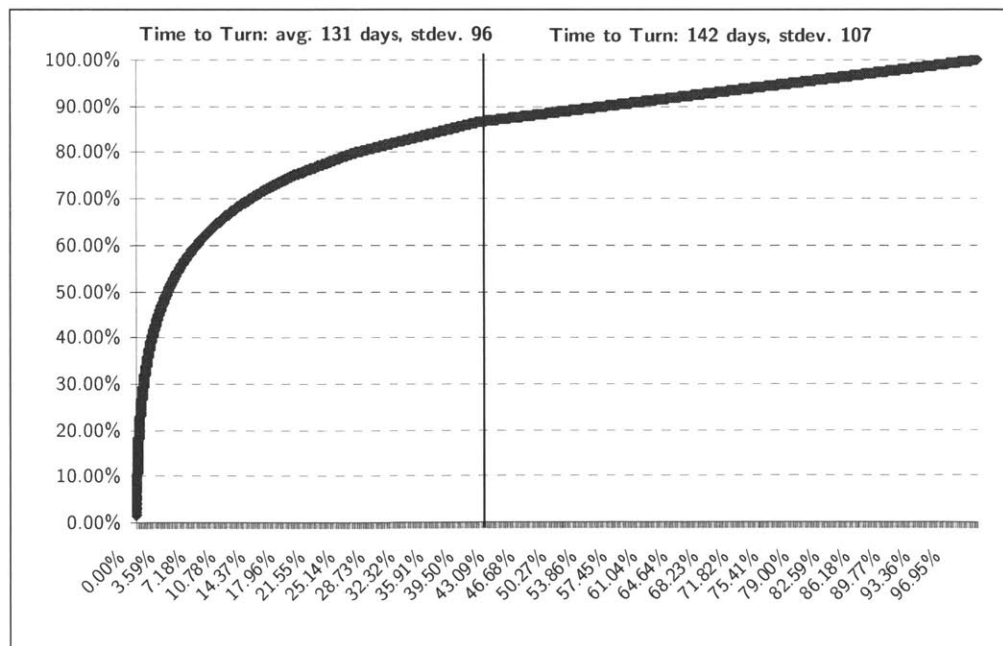
Source: dataset provided by GM (models and order numbers have been disguised)

Figure 7-6: Sample order cycle



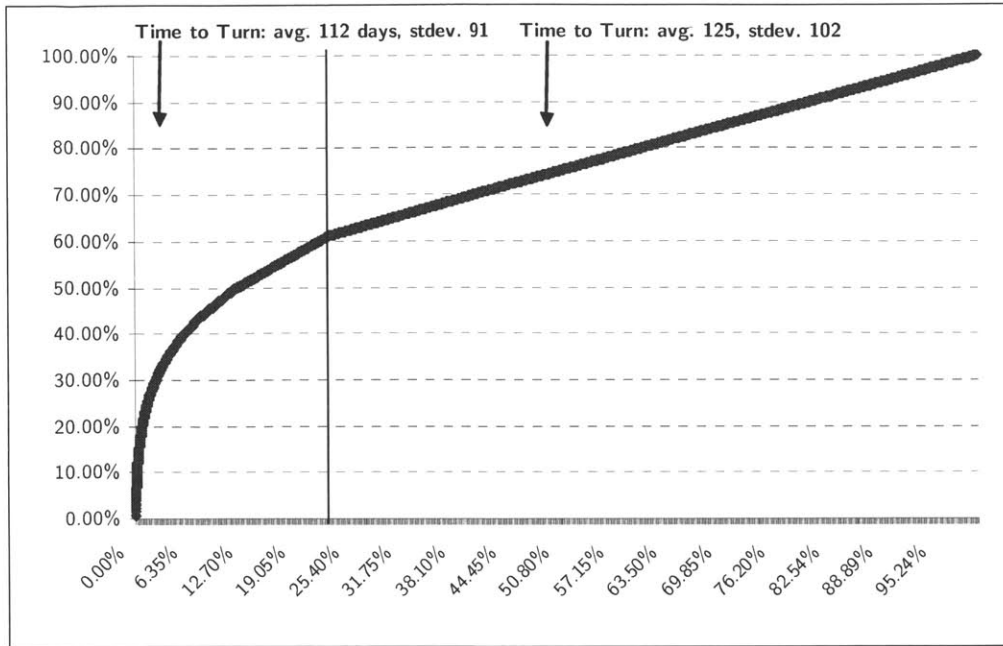
Source: GM; dataset of individual sales. Note logarithmic scales in both axis. Scales have been eliminated for confidentiality.

Figure 7-7: Number of different configurations vs sales volume for GM brands



Source: dataset provided by GM

Figure 7-8: Pareto of models vs volume sold for a High Volume / Medium Variety Brand



Source: dataset provided by GM

Figure 7-9: Pareto of models vs volume sold for a High Volume / High Variety Brand

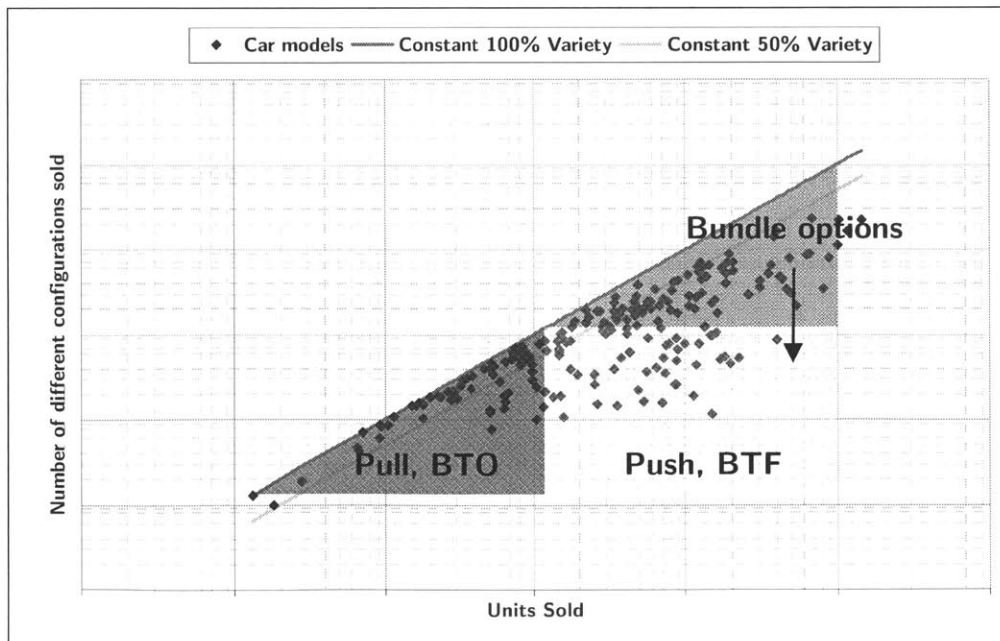
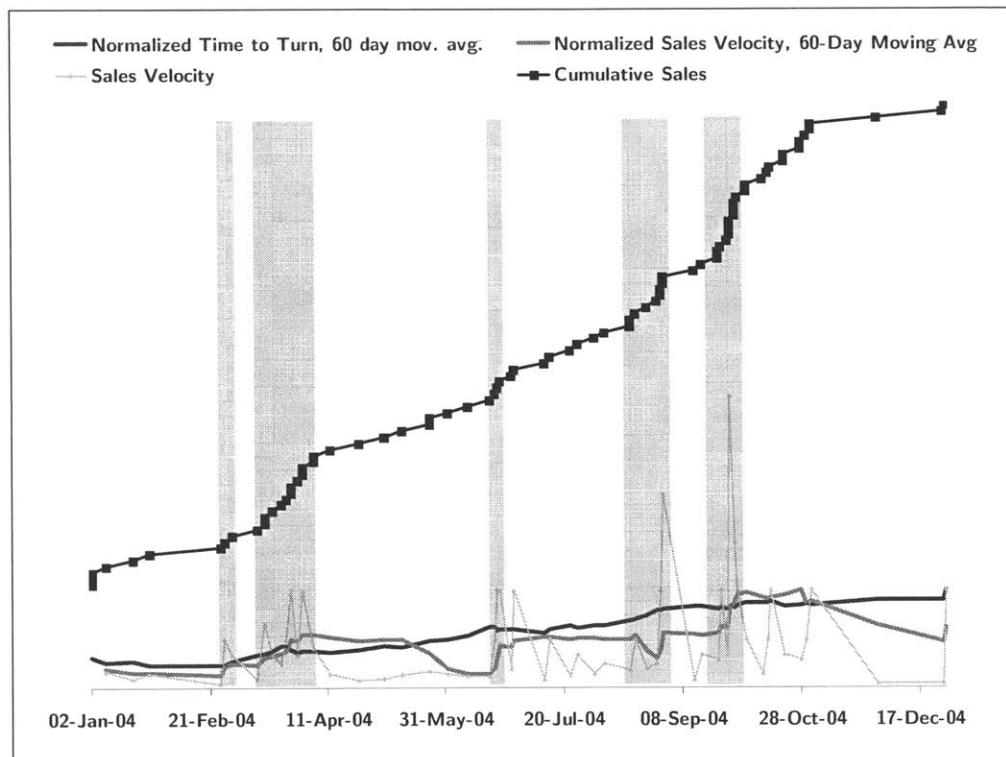


Figure 7-10: Managing Variety



Source: dataset provided by GM

Figure 7-11: Inventory Velocity for a volume model in a certain region

# Chapter 8

## Conclusions

### **Why a paradigm shift is needed**

From the perspective of this thesis, designing a supply chain is nothing but an optimization problem where we attempt to maximize the performance of a supply chain—whatever this may mean in the context of each business—by taking decisions over a number of design degrees of freedom, and conforming to a number of constraints.

In past, in what we called “the classic view,” the optimization objective was minimizing costs, and the degrees of freedom were limited to basically a number of decisions on how to lay out the distribution network and what kind of inventory policy to follow. This way of designing supply chains had the advantage of addressing the most important concerns, while being simple, and it has indeed been very successful. However, as we push the supply chains for greater performance, we start experiencing its limitations, and we feel pressured to broaden the scope of the problem in order to drop some of constraints in the seek of globally optimal designs.

These changes require also a change of mindset—from reducing cost to maximizing value, from narrow focus on the supply/distribution network to broad consideration of peripheral elements such as sourcing, sales, or product design. As we broaden the scope of the problem, however, we also increase its complexity, and we need new methods of analysis and design that can handle this complexity integrally, avoiding oversimplification.

## What makes supply chain architecture hard

Too often frameworks attempt to give prescriptive advice on a limited set of design decisions—typically one—based on a limited set of input variables—too often two variables. Chapter 5 has presented a fair number of examples.

Conceptually, this is a valuable exercise, since it helps identifying the key factors to consider when taking a design decision. The problem arises when one attempts to describe a complete architecture—that is, a complete set of decisions over a number of design degrees of freedom—since the fundamental assumption of these frameworks is violated: that all other factors remain unchanged.

When designing a supply chain architecture, we face a fundamental problem of system design: that the whole is greater than the sum of the parts, that the interactions between the parts can be as important as the parts themselves. In this situation, all these frameworks are of limited help, and new, systemic approaches that take into consideration all the factors and their inter-relationships are required. This is the first, and most important problem in supply chain architecture: how to describe and analyze interactions between the effects of design decisions, and the tradeoffs—real or apparent—among supply chain objectives. It has been discussed in chapter 4 and chapter 5 proposed a template for describing complex design situations and the inherent tradeoffs that one must have in mind when taking design decisions.

The second problem is a more subtle one: how can we compare two different architectures at the “drawing board” level? How can we determine that a certain supply chain architecture is more appropriate than another? The easy response, we concluded, is that architecture can only separate the designs that are *obviously wrong* from the ones that are *possibly right*. Only at the detailed design level is it possible to actually make a meaningful comparison.<sup>1</sup>

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<sup>1</sup>MIT’s Prof. Edward Crawley calls this fundamental problem in Systems Architecting the “two levels down, one up” decomposition problem – in order to evaluate two different architectures, one must go down to one additional level of decomposition.

## **Recurrent ideas in the frameworks**

We have identified five key environmental variables that are pervasive to prescriptive supply chain design frameworks: lead times, demand risk, clockspeed, economies of scale, and product/process modularity. Clockspeed and demand risk largely determine the strategic focus of the supply chain. Economies of Scale and Demand Risk appear to be the most important factors when deciding between push and pull strategies. Lead times acts as a multiplier of demand risk and has important implications for lay out of the distribution network, and more specifically for deciding where push/pull boundaries can be feasibly placed.

While the interactions among these factors are not evident, one of the fundamental ideas we present is that specific actions can be taken at the Product Development Process level and at the Supply Chain level to reduce the interaction between the different variables of interest—for example, commonality plans, component standardization, and product platforms can be used to share costs across product lines, hence increasing economies of scale with limited impact on supply chain flexibility and inventory risk. In this aspect, good supply chain architectures will be able to decouple key factors—e.g. the right product and supply chain architecture allows offering high external variety with limited internal variety.

## **Time for a Pattern Language**

Architecting a supply chain needs a common language suitable for expressing the design problem. The L-model presented in chapter 3 is an starting point, but it is not enough.

In chapter 5 we proposed a simple prescriptive framework for aligning supply chain strategic focus and the L-model's Fulfillment and Development supply chains; however, we don't advocate for this kind of frameworks. Templates for documenting high level design degrees of freedom and the tradeoffs involved such as those presented in figure 5-9 allow for a richer description of the rationale of the decision to be made, the assumptions, prerequisites, and potential interactions with other factors. This

method is close to the concept of pattern languages and design patterns, which are used in disciplines such as Civil Architecture and Software Engineering to convey design decisions.

In general, design patterns are appropriate whenever the design problem is complex and the architect must bear in mind important tradeoffs before making a decision. As supply chain management moves into the new view, we believe that pattern languages are more appropriate for describing the complex decisions to be made. Some known design patterns already exist, although possibly not with that name (e.g. surge/base split, moving the push/pull boundary, channel split, etc.—a non-exhaustive list has been provided); however, nobody appears to have yet attempted to build a body of knowledge of supply chain design patterns.

### **Zara and GM: isolated cases, or a sign of the times?**

Zara and GM are two interesting opposites. According to the classic view, Zara is doing what one should never do—and that is doing it very successfully. It is the embodiment of the “new view.” their supply chain is not cost-effective, but it is value-driven and supports the strategy of the company.

In contrast, GM has been doing the right thing according to the classic view—keeping utilization factors high and inventories lean at the factories, pushing providers for lower costs... and it is backfiring in the long term. Zara reminds us that capacity utilization is, by itself, meaningless, and that indeed, idle capacity builds options whose value is often ignored. However, for GM it is hard to ignore capital investments upstream, hence the paradox that by doing the *right* thing, GM is doing the *wrong* thing.

At the core, Zara’s vertical integration vertebrates the supply chain and aligns the incentives of the different parties in the Supply Chain, ensuring that information flows seamlessly and the demand signal is fed back upstream without delay or distortion. This is the single most important requirement for their operations: Zara is an extreme case of a pull-based system: when store managers make orders and talk to product managers, not only the demand signal triggers production, it also triggers the product



development process—demand effectively *pulls* at the product design level.

In comparison, GM is a case of a push-based system, where production is almost entirely driven by a forecast, and the only people in direct contact with the customer, the dealers, have limited freedom to order according to their best interest—and also limited liability compared to Zara, where stores experience first hand the consequences of the accuracy of their forecasts. Dealers are also out of the design loop and GM must rely on interpreting proxy signals, such as ordering patterns from dealers, or attempting to establish an alternative demand sensing channel to drive their product design and development process.

Theoretically, it should be possible to obtain the same results with the right system of incentives, as Dell's model suggest, but GM reminds us that first, it is tough to find the right system, and second, even when the right system is in place, it is hard to change and make it to evolve to adapt to changes in the market. Can GM feasibly change their dealer financing policies—those 90-days of financing? It's difficult. Can GM rationalize variety and bundle options in their vehicles? Possibly, but not in the short term. Dell can sense the demand without distortion and transmit it upstream to the factories; furthermore Dell's dynamic pricing demand steering mechanisms are equally applied without distortion, whereas in the case of GM complex situations derive from the interaction between customer preferences and dealers' agenda.

Demand sensing will therefore become increasingly important as clockspeed and demand uncertainty increase. In this situation, managing the supply chain is much like driving over ice: accelerating improves steering. Zara is an outstanding example—by introducing products faster, Zara receives feedback from the market faster, clearing out demand uncertainty and controlling the risk of obsolescence. But in order to do it, a responsive supply chain and a flexible production system are needed—both things that GM can't afford, trapped upstream by capital investments and downstream by channel lock-in, and pushed to generate cash by capital markets.

There are things that GM can do, though. The L-model tells us that we can, and should seek at the boundaries of the classic supply chain to solve problems *inside* the classic supply chain. This idea was illustrated with two initiatives in the context

of a transition model from a push-based system to a pull-based system: one at the product design level (aligning product variety with the reality of the supply chain), and another at the sales level (using inventory velocity or throughput to get a better estimate of market pull).

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